(12) **EUROPEAN PATENT APPLICATION**

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(54) **Two-stage coal gasification process.**

(57) The invention provides a two-stage upflow process for coal gasification. An oxygen-containing gas and a first increment of a coal-in-water slurry are ignited in a horizontal fired slagging reactor (3) by means of horizontal coaxial juxtaposed burner nozzles (6, 6a) mounted in the reactor, thereby converting the oxygen, the coal, and the water into steam and gaseous combustion products. The discharge from the fired reactor is contacted overhead with a second increment of coal-water slurry (8) in a vertical unfired heat-recovery unit (4) connected to the upper end of the reactor. The heat evolved in the reactor is used in the heat recovery unit to convert the second increment of coal-water slurry into more steam, char and synthesis gas. The gas effluent is separated from the solid char, and synthesis gas is recovered as the desired fuel-rich product. The solid char is reslurried and recycled to the fired reactor (3) for further combustion.

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TWO-STAGE COAL GASIFICATION PROCESS

This invention relates to the gasification of carbonaceous materials. More particularly, the invention relates to the conversion of a solid carbonaceous fuel into gaseous products having increased fuel value.

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Three basic processes have been developed for the gasification of carbonaceous materials such as coal. They are: (1) fixed-bed gasification, (2) fluidized-bed gasification, and (3) suspension or
10 entrainment gasification. The present invention relates to the third type of process, suspension or entrainment gasification.

An inherent disadvantage of entrainment
15 gasifiers is that they generate hot product gases. The heat must be recovered from the gases in order to utilize fully the heating value of the coal. It is known to quench partial oxidation gasification reactions directly in water or steam according to U.S.
20 2,957,387, U.S. 3,000,711 and U.S. 3,723,345, or to partially cool the effluent gases by indirect heat exchange, as taught in U.S.3,025,149. However, large

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amounts of heat are lost without enhancing the fuel value of the synthesis gas produced.

Some of the reactions in a coal gasifier are exothermic and some are endothermic. A coal-gasification process in which the heat generated by the exothermic reactions is used to provide the heat required for the endothermic reactions would be extremely desirable and energy efficient. Thus, it is an object of the present invention to provide an exothermic reactor partially oxidizing carbonaceous material with an oxygen-containing gas combined with a heat recovery unit to permit the endothermic reactions to proceed efficiently by reacting additional carbonaceous material with water, producing enhanced quality synthesis gas. This and other objects are accomplished in accordance with the present invention as described hereinbelow.

In general, the present invention provides a non-catalytic two-stage upflow process for gasification of carbonaceous fuels. The first stage or step of the process comprises the combustion, in a fired horizontal slagging reaction zone, or first stage reactor, of a stream of oxygen-containing gas and a first increment of a slurry of particulate carbonaceous solids in a liquid carrier. The solids concentration of the slurry may be from 30 to 70 percent by weight. Combustion usually occurs at a temperature between 2400°F (1300°C) and 3000°F (1650°C) in the horizontal reactor zone by using opposed. facing horizontal burner nozzles. Preferably. the horizontal burner nozzles are also coaxial, but this is not required. The oxygen. carbonaceous solids and liquid carrier are converted into steam. vapor from the liquid carrier. slag. char. and gaseous combustion

products. The slag which forms in the reactor flows by
gravity to the bottom of the reactor and out of the
reactor through a tap hole.

5   In the second stage, or step, the steam, vapor
from the liquid carrier, char, and gaseous combustion
products from the fired horizontal reactor are
contacted, in an unfired vertical heat recovery unit,
or second stage reactor, with a second increment of
10 slurry of particulate carbonaceous solids in a liquid
carrier to yield steam, vapor from the liquid carrier,
synthesis gas and char entrained in the gaseous
effluent. As used herein, the term "unfired" means
that further combustion is not promoted by the addition
15 of a second oxygen-containing gas stream. The vertical
heat recovery unit does not promote additional combus-
tion and exothermic reactions such as which occur in
the fired horizontal reactor. In the vertical heat
recovery unit, endothermic reactions predominate using
20 heat produced by the combustion in the fired horizontal
reactor. The second increment of particulate
carbonaceous solids in a liquid carrier is injected
into the vertical heat recovery unit by means of a
25 nozzle, with steam or other atomizing gas for
atomization of the slurry of particulate carbonaceous
solids to provide better reaction. Injecting the
second increment of slurry at a point downstream of the
original injection point reduces the temperature of the
30 gases exiting from the fired horizontal reactor and
provides a more efficient use of the heat removed in
the process. Thus, while the fired horizontal reactor
is primarily a combustion reactor, the vertical heat
35 recovery unit is primarily a quench reactor which
increases the heating value of the gases. The solids

concentration of the second increment of slurry is from 30 to 70 percent by weight. The temperature of the vertical heat recovery unit usually is from 1600°F (850°C) to 2000°F (1100°C). In a preferred embodiment of the

5   present process, the unfired vertical heat recovery unit is connected directly to the top of the fired horizontal reactor so that the hot reaction products are conveyed directly from the horizontal reactor to the heat recovery unit to minimize heat losses in the

10   gaseous reaction products and entrained solids. Direct connection also has the advantage of maintaining temperatures to prevent the slag formed from cooling in the horizontal reactor and forming solid deposits.

15   The synthesis gas and char entrained in the gaseous effluent from the unfired vertical heat recovery unit exit from the top and can be separated in a cyclone separator. The char exiting the cyclone separator can be mixed with a liquid carrier forming a

20   dilute slurry which is thereafter concentrated in a settling tank to a solids concentration of from 10 to 30 percent by weight. Then from 5 to 20 percent of the concentrated, or recycle, char slurry, based on the

25   total amount of solid carbon fuel to the first stage, can be added to the first stage horizontal slagging reactor zone, preferably after mixing with one or more streams of particulate carbonaceous solids comprising the first increment fed to the horizontal fired slagging reactor.

30   The figure of the drawing is a schematic representation of apparatus useful in and a pictorial process flow diagram for carrying out a preferred embodiment of the process of the present invention.

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The following description illustrates the manner in which the principles of the present invention are applied, but is not to be construed in any sense as limiting the scope of the invention.

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More specifically, as shown in Figure 1, first and second streams comprising oxygen or an oxygen-containing gas, such as, for example, air or oxygen-enriched air, and a first increment of a slurry of
10 particulate carbonaceous solids and liquid carrier enter apparatus 1 through mixing nozzles 6 and 6a, respectively. Mixing nozzles 6 and 6a are located oppositely in and extend through ends 10 and 11, respectively, of horizontal fired slagging reactor 3.
15 Within horizontal fired slagging reactor 3, the feed streams are converted exothermically into steam, slag, char, vapor from the liquid carrier, hydrogen, carbon monoxide, carbon dioxide and minor amounts of other
20 gases. The slag formed as a by-product is drained from the bottom of the reactor 3 through a tap hole 2, to a slag quench section 9 and continuous depressurizing system (not shown). As the steam, char and intermediate gases leave the reactor 3, they flow
25 upward into an unfired heat recovery unit 4 where a second increment of a slurry of particulate carbonaceous solids and liquid carrier is injected through nozzle 8. The heat produced in the reactor 3 and carried upward is used to effect the endothermic
30 processes which take place in heat recovery unit 4 including vaporization of the feed water, the carbon-steam reaction and the water-gas reaction between the CO and H_2O. The carbon-steam reaction forms CO and H_2,
35 thus increasing the yield of these usable gases. In the last reaction, carbon monoxide reacts with water or

steam to form carbon dioxide and additional hydrogen.
The reactions occurring in heat recovery unit 4 thus
enrich the intermediate gases and produce a higher
grade of synthesis gas.

The mixing, or two-fluid, nozzles 6 and 6a
provide an atomized feed of the particulate
carbonaceous solids slurry giving more efficient
combustion of the carbonaceous solids. Preferably, the
nozzles are of the type having a central tube for the
slurry and an annular space surrounding the central
tube containing the atomizing gas which opens to a
common mixing zone internally or externally to provide
for the atomization of the slurry. Further, the
injection nozzle 8 of the unfired heat recovery unit 4
can also be a nozzle of the type described hereinabove.
Both mixing nozzles 6 and 6a and injection nozzle 8 can
be of the internal or external mixing type, as is
conventionally known to those skilled in the art.

As further shown in Figure 1, the effluent from
the heat recovery unit 4 is sent to a cyclone separator
5 which splits the effluent into a solids stream and a
gas stream, which includes the synthesis gas. The gas
stream comprises hydrogen, carbon monoxide, a small
amount of methane, H_2S, ammonia, water vapor or steam,
vapor from the liquid carrier, nitrogen and carbon
dioxide. The solids stream comprises ash and char
formed in the heat recovery unit 4 or carried over from
the horizontal reactor 3. The synthesis gas is
recovered as the desired fuel-rich product, and the
char is formed into a low concentration slurry,
settled, combined and recycled with fresh carbonaceous

solids/liquid carrier slurry and recycled to the reactor 3, as more fully described below.

The solids stream, comprising char and ash, separated from the gas stream in cyclone separator 5, contacts a liquid carrier to form a dilute slurry and goes to a settling vessel 7 for concentration. The settling vessel 7 may include separation and evaporation means (not shown) to provide a more concentrated slurry. A stream exiting vessel 7 forms a recycle char slurry stream. The preferred recycle slurry of char and liquid carrier defines a solids concentration of from 20 to 40 percent by weight, more preferably from 30 to 40 percent by weight. The slurry of char and liquid carrier may have a higher percentage of solids, however, too high a solids concentration makes the feed to fired horizontal reactor 3 too viscous for convenient pumping. It is desirable to mix the recycle slurry of char and liquid carrier with the feed slurry particulate carbonaceous solids and liquid carrier in a mixing vessel 7a before it is transferred into fired horizontal reactor 3 through mixing nozzles 6 and 6a.

The materials of construction of the reactor 3 and heat recovery unit 4 are not critical. Preferably, but not necessarily, the vessel walls are steel and are lined with an insulating castable or ceramic fiber or refractory brick, such as dense phase magnesia-chromia spinel, a magnesia-aluminate spinel, or a high chrome--zirconia brick, all of which are commercially available from several sources. Use of this type of system provides the high recovery of heat values from the carbonaceous solids used in the process. Optionally and alternatively, the walls may be unlined

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pressures. Generally, the pressure in reactor 3 is from 50 psig (350 kPa gauge) to 450 psig (3100 kPa gauge). At pressures greater than 450 psig (3100 kPa gauge), the capital cost of high pressure reaction

5 equipment makes the process economically less attractive; while at pressures lower than 50 psig (350 kPa gauge), the throughput of the gaseous products in the reactor 3 and heat recovery unit 4 is lower than economically attractive. Preferably, the process runs

10 at pressures of from 100 psig (700 kPa gauge) to 400 psig (2750 kPa gauge) and, most preferably, from 250 to 400 psig (1700 to 2750 kPa gauge).

15 The process is applicable to any particulate carbonaceous material. Moreover, the nature and concentration of the carbonaceous material in the two stages need not be the same. Preferably, however, the particulate carbonaceous material is coal which,

20 without limitation, includes lignite, bituminous coal, sub-bituminous coal, or any combination thereof. Additional carbonaceous materials are coke from coal, coal char, coal liquefaction residues, particulate carbon, petroleum coke, carbonaceous solids derived

25 from oil shale, tar sands, pitch, concentrated sewer sludge, bits of garbage, rubber and mixtures thereof. The foregoing exemplified materials can be in the form of comminuted solids or as pumpable slurries in a liquid carrier.

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Additional carbonaceous materials are liquid hydrocarbonaceous fuels such as various liquid hydrocarbon fuels including petroleum distillates and residue, gasoline, kerosene, naphtha, gas oil, residual

35 fuel, reduced crude, fuel oil, crude petroleum, coal tar, coal-derived oil, shale oil, tar sand oil,

liquified petroleum gas, aromatic hydrocarbons (such as
benzene, toluene and xylene fractions), cycle gas oil
from fluid-catalytic-cracking operations, furfural
extract of coker gas oil, and mixtures thereof.

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Other carbonaceous materials include liquid
oxygenated hydrocarbonaceous materials, that is, liquid
hydrocarbon materials containing combined oxygen,
including carbohydrates, cellulosic materials,
10 oxygenated fuel oil, waste liquids and by-products of
chemical processes for oxygenated hydrocarbonaceous
materials, alcohols, ketones, aldehydes, organic acids,
esters, ethers, and mixtures thereof. Also, the liquid
hydrocarbonaceous materials above may be in admixture
15 with one of the previously described carbonaceous
materials.

Of course, when the carbonaceous material
employed is a liquid hydrocarbonaceous material, a
20 liquid carrier may not be required. Further, it may be
necessary to add additional water, as a liquid or in
the form of steam to provide a sufficient amount for
reaction with carbon to form the desired synthesis gas.

The liquid carrier for carbonaceous solid
25 materials can be any liquid which is capable of
vaporizing and participating in the reactions to form
desired gaseous products, particularly carbon monoxide
and hydrogen. The most readily considered liquid
30 carrier is water which forms steam in both reactor 3
and heat recovery unit 4. The steam is capable of
reacting with carbon to form gaseous products which are
constituents of synthesis gas. In addition, liquids
other than water may be used to slurry the carbonaceous
35 material. Preferably, the liquid is water, but it may
also be a hydrocarbon such as, for example, fuel oil,

residual oil, petroleum, and liquid CO_2. When the liquid carrier is a hydrocarbon, additional water or steam may be added to provide sufficient water for efficient reaction.

Any gas containing at least 20 percent oxygen may be used as the oxygen-containing gas fed to fired horizontal reactor 3. Preferred oxygen-containing gases include oxygen, air, and oxygen-enriched air with air as the oxygen-containing gas, the initial atomic ratio of free elemental oxygen to carbon in the reactor 3 is from 1.5:1 to 2.5:1. With oxygen, the ratio is from 1:1 to 2:1.

The concentration of particulate carbonaceous material in the carrier liquid as a slurry is only that necessary to have a pumpable mixture. This generally ranges up to 70 percent by weight of the solid material. Preferably, the concentration of particulate carbonaceous material in the slurry ranges from 30 percent to 70 percent by weight in both the first and second stages of the process. More preferably, the concentration of coal in aqueous slurry is between 45 and 55 percent by weight.

When coal is the feedstock, it is pulverized before being blended with a liquid carrier to form a slurry. In general, any reasonably finely-divided carbonaceous material may be used, and any of the known methods of reducing the particle size of particulate solids may be employed. Examples of such methods include the use of ball, rod and hammer mills. While particle size is not critical, finely divided carbon particles are preferred. Powdered coal used as fuel in coal-fed power plants is typical. Such coal has a

particle size distribution in which 90 percent by
weight of the coal passes through a 200 mesh sieve,
Tyler series (0.07 mm).

5   The present invention is illustrated by the
following examples, which are not to be construed as in
any sense limiting the scope of the invention.

Example 1

.10   A slurry at 80°F (27°C) containing 52 percent
pulverized sub-bituminous coal, i.e., Western Coal, and
48 percent water by weight was injected into the fired
horizontal reactor 3 at a rate of 52 gallons/minute
(195   liters/minute), together with a stream of air
15 at 950°F (510°C) flowing at a rate of 90,000 pounds/hour
41,000 kg/hr). The temperature within the reactor 3
was 2600°F (1430°C) and the pressure was 120 psig
(825 kPa gauge   ). The steam and hot product gases
20 made in the reactor 3 were passed upward into the
unfired heat recovery unit 4, where they were contacted
with a second increment of slurry at 80°F (27°C)
containing 52 percent pulverized sub-bituminous coal
and 48 percent water by weight, flowing at a rate of 20
25 gallons/minute (75   liters/minute), along with
atomizing steam at 465°F (240 °C) flowing at a rate of
7,000 pounds/hour (3200 kg/hr).

           In the heat recovery unit 4, the heat generated
30 in the reactor 3 was absorbed by the second increment
of slurry, and used to convert the slurry into more
steam and gaseous products. The temperature within the
heat recovery unit 4 was 1800°F (980°C). The steam and
35 gaseous products were discharged from the heat recovery
unit 4 to the cyclone separator 5, where the mixture

was separated into a gaseous stream and a solids
stream. The discharge from the reactor 3 comprised
10.4 percent hydrogen, 10.4 percent carbon monoxide,
15.0 percent carbon dioxide, 0.04 percent methane, and
5 65.0 percent nitrogen on a dry basis. The gas stream
discharged from the cyclone separator 5 at a rate of
100,000 pounds/hour (45,000 Kg/hr) and comprised 11.8
percent hydrogen, 8.8 percent carbon monoxide, 15.4
percent carbon dioxide, 0.5 percent methane, and 63.4
10 percent nitrogen by volume on a dry basis. The solids
were mixed with water at 200-300°F (95 to 150°C) flowing
at a rate of 300 gallons/minute (1100 liters/minute)
to form a slurry which can be concentrated to 25
percent solids by weight and recycled to the fired
15 reactor 3 or discharged to waste treatment, as desired.

Example 2

A slurry at 80°F (27°C) containing 50 percent
20 pulverized sub-bituminous coal and 50 percent water by
weight was injected into the fired horizontal reactor 3
at a rate of 52 gallons/minute (195 liters/minute),
together with a stream of air at 950°F (510°C) flowing
at a rate of 90,000 pounds/hour (41,000 Kg/hr). The
25 temperature within the reactor 3 was 2650°F (1450°C) and
the pressure was 110 psig (760 kPa gage). The steam
and hot product gases made in the reactor 3 were passed
overhead into the unfired heat recovery unit 4, and
were there contacted with a second increment of slurry
30 at 80°F (27°C) containing 40 percent pulverized sub-
bituminous coal and 60 percent water by weight, flowing
at a rate of 28 gallons/minute (105 liters/minute),
along with atomizing steam at 465°F (240°C) flowing at
35 a rate of 7,000 pounds/hour (3200 kg/hr). In the
heat recovery unit 4, the heat generated in the reactor

3 was absorbed by the second increment of slurry, and used to convert the slurry into more steam and gaseous products. The temperature within the heat recovery unit 4 was 1800°F (980°C). The steam and gaseous

5 products were discharged from the heat recovery unit 4 to the cyclone separator 5., where the mixture was separated into a gaseous stream and a solids stream. The gaseous products discharged overhead from the reactor 3 comprised 9.5 percent hydrogen, 10.2 percent

10 carbon monoxide, 16.5 percent carbon dioxide, 0.07 percent methane, and 63.6 percent nitrogen on a dry basis. The gaseous products discharged overhead from the cyclone separator 5 at a rate of 112,000 pounds/hour (51,000 kg/hr) comprised 12 percent

15 hydrogen, 10.0 percent carbon monoxide, 11.0 percent carbon dioxide, 0.5 percent methane and 66.4 percent nitrogen on a dry basis. The solids were mixed with water at 200-300°F (95 to 150°C) flowing at a rate of

20 300 gallons/minute (1100 liters/minute) to form a slurry which can then be concentrated to 25 percent solids by weight and recycled to the fired reactor 3 or discharged to waste treatment, as desired.

25 Example 3

In this example, a slurry of pulverized lignite and water was used as feed to a reactor similar to that illustratively shown as the apparatus 1 of Figure 1.

30 Oxygen of 99.6 percent purity was used as the oxygen-containing gas instead of air.

A slurry at 75°F (24°C) containing 44.5 percent dry lignite by weight was injected into the

35 fired horizontal reactor 3 at a rate of 2930 pounds/hour (1300 kg/hr), together with oxygen at 63°F

(17°C) flowing at a rate of 1621 pounds/hour (735 Kg/hr). The temperature within the reactor 3 was 2500°F (1371°C), and the pressure was 240 psig (1650 kPa gage). One hundred pounds/hour (45 kg/hr) of nitrogen was

5 added to the fired horizontal reactor 3 via instrument purges. The steam and hot product gases generated in the fired horizontal reactor 3 were passed upward into the unfired heat recovery unit 4, and were there contacted with a second increment of slurry at 75°F

10 (24°C) containing 44.5 percent dry lignite by weight flowing at a rate of 874 pounds/hour (396 Kg/hr), along with atomizing steam at 465°F (240°C) flowing at a rate of 161 pounds/hour (73 kg/hr). In the heat

15 recovery unit 4, heat generated in the fired horizontal reactor 3 was absorbed by the second increment of slurry, and used to convert the slurry into more steam and gaseous products. The temperature within the heat recovery unit 4 was 1840°F (1005°C). The steam and

20 gaseous products were discharged from the heat recovery unit 4 into the cyclone separator 5, where the mixture was separated into a gaseous stream and a solids stream. The solids stream was added to water and discharged. The discharge from the reactor 3 comprised

25 43.3 percent hydrogen, 26.6 percent carbon monoxide, 23.3 percent carbon dioxide, 0.8 percent methane, and 5.9 percent nitrogen by volume on a dry basis. The gas stream discharged from the cyclone comprised 48.8

30 percent hydrogen, 22.2 percent carbon monoxide, 23.3 percent carbon dioxide, 2.2 percent methane, and 3.5 percent nitrogen by volume on a dry basis.

Example 4

35 A slurry at 200°F (93°C) containing 49.5 percent pulverized sub-bituminous coal and recycled

char, the net being 50.5 percent water by weight, was injected into the fired horizontal reactor 3 at a rate of 86 gallons/minute (325 liters/minute), together with a stream of oxygen flowing at a rate of 29,200

5   pounds/hour (13,250 kg/hr). The feed slurry was a mixture of 0.926 volume fraction sub-bituminous coal slurry at 51 percent solids and 0.074 volume fraction char slurry at 30 percent solids. The temperature within the reactor 3 was 2840°F (1560°C) and the

10   pressure was 120 psig (825 kPa gage). The steam and hot product gases made in the reactor 3 were passed overhead into the unfired heat recovery unit 4, and were there contacted with a second increment of slurry

15   at 90°F (32°C .) containing 50 percent pulverized sub-bituminous coal and 50 percent water by weight, flowing at a rate of 25 gallons/minute (95 liters/minute), along with atomizing steam at 465°F (240°C) flowing at a rate of 7,000 pounds/hour (3200 kg/hr). In the

20   heat recovery unit 4, the heat generated in the reactor 3 was absorbed by the second increment of slurry, and used to convert the slurry into more steam and gaseous products. The temperature within the heat recovery unit 4 was 1920°F (1050°C). The steam and gaseous

.25   products were discharged from the heat recovery unit 4 to the cyclone separator 5, where the mixture was separated into a gaseous stream and a solids stream. The gaseous products discharged overhead from the

30   reactor 3 comprised 32.7 percent hydrogen, 31.5 percent carbon monoxide. 30.5 percent carbon dioxide. 0 percent methane. and 5.3 percent nitrogen on a dry basis. The gaseous products discharged overhead from the cyclone separator 5 at a rate of 50.504 pounds/hour (22,900

35   kg/hr) comprised 36.1 percent hydrogen. 26.7 percent carbon monoxide, 31.8 percent carbon dioxide. 0.5

percent methane and 4.9 percent nitrogen on a dry
basis. The solids from the bottom of the cyclone were
mixed with water at 200 to 300°F (95 to 150°C) flowing at
a rate of 300 gallons/minute (1135   liters/minute) to
form a slurry which was then concentrated to about 25
percent solids by weight and recycled to the fired
reactor 3.

While certain representative embodiments and
details have been shown for the purpose of illustrating
the present invention, it will be apparent to those
skilled in the art that various changes and
modifications can be made therein without departing
from the scope of the invention as defined in the
following Claims.

CLAIMS:

1.   A non-catalytic two-stage upflow process for
gasification of a carbonaceous material, which process
comprises

05   (a)   combusting in a fired horizontal slagging

                 reactor a stream comprising an oxygen-

                 containing gas and a first increment of a

                 liquid carbonaceous material and/or a slurry

                 of particulate carbonaceous material in a

10   liquid carrier by means of opposed

                 horizontal burner nozzles, thereby evolving

                 heat and converting the oxygen, the

                 carbonaceous material, and the carrier

                 liquid into steam, vapor from the carrier

15   liquid, slag, char, and gaseous combustion

                 products; and

          (b)   contacting, in an unfired vertical heat

                 recovery unit, the steam, vapor from the

                 carrier liquid, char, and gaseous combustion

20   products from the fired horizontal reactor

                 with a second increment of a liquid

                 carbonaceous material and/or a slurry of

                 particulate carbonaceous material in a

                 liquid carrier, thereby recovering the heat

25   evolved in the reactor and converting the

                 carbonaceous material and carrier liquid

into steam, vapor from the carrier liquid, synthesis gas and char.

2.   A process as claimed in Claim 1, wherein the said slagging reactor is operated at a temperature of 1300°C (2400°F) to 1650°C (3000°F) and at a pressure of from 350 kPa gauge (50 psig) to 3100 kPa gauge (450 psig) and the said recovery unit is operated at a temperature of 850°C (1600°F) to 1100°C (2000°F).

3.   A process as claimed in Claim 1 or Claim 2, further comprising the step of:

   (c)   draining the slag formed in the fired horizontal slagging reactor from the bottom of the reactor.

4.   A process as claimed in any one of the preceding claims, further comprising the step of:

   (d)   recycling to step (a) the char formed in step (b) as a suspension in a liquid defining a solids concentration of from 20 percent to 40 percent by weight.

5.   A process as claimed in Claim 4, wherein step (d) further comprises the steps of:

   (d$_1$)   separating the char from the synthesis gas;

   (d$_2$)   contacting the char with the liquid thereby forming the suspension of char in the liquid; and

(d₃)   recycling the char suspension to the fired reactor.

6. A process as claimed in any one of the preceding claims, wherein the carbonaceous material is introduced with water as a carrier liquid.

7. A process as claimed in any one of the preceding claims, wherein the carbonaceous material is introduced as a slurry having a solids concentration of from 30 to 70 percent by weight.

8. A process as claimed in Claim 7, wherein the said solids concentration is 45 to 55 percent by weight.

9. A process as claimed in any one of the preceding claims, wherein the oxygen-containing gas is air, oxygen-enriched air, or oxygen.

10. A process as claimed in any one of the preceding claims, wherein the oxygen-containing gas is air and the initial atomic ratio of free elemental oxygen to carbon in the reactor is between 1.5:1 and 2.5:1.

11. A process as claimed in any one of the preceding claims, wherein said carbonaceous material is coal or lignite.

12. A process as claimed in any one of the preceding claims, wherein said unfired vertical heat recovery unit is connected to the top of said fired horizontal reactor.
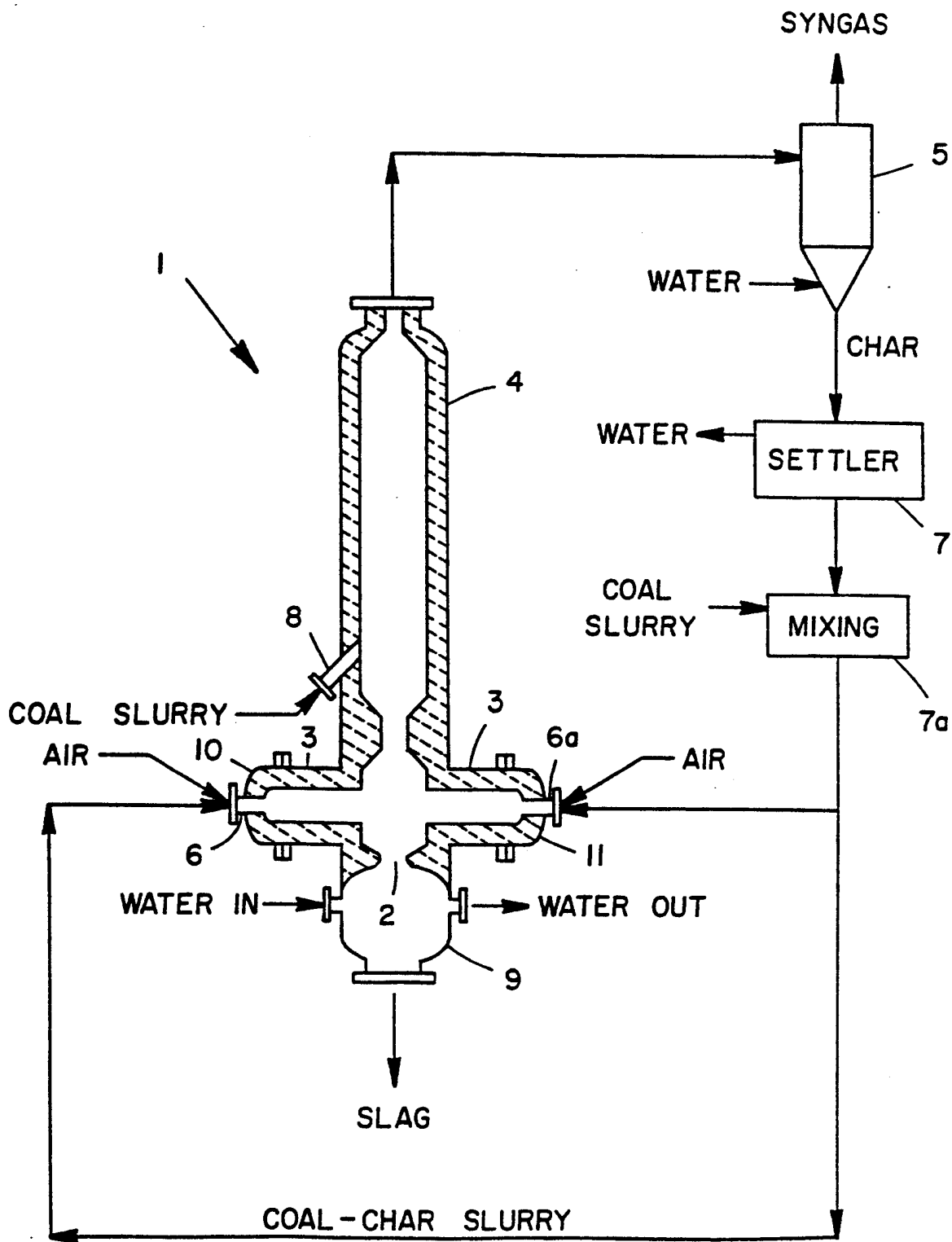
FIG.1