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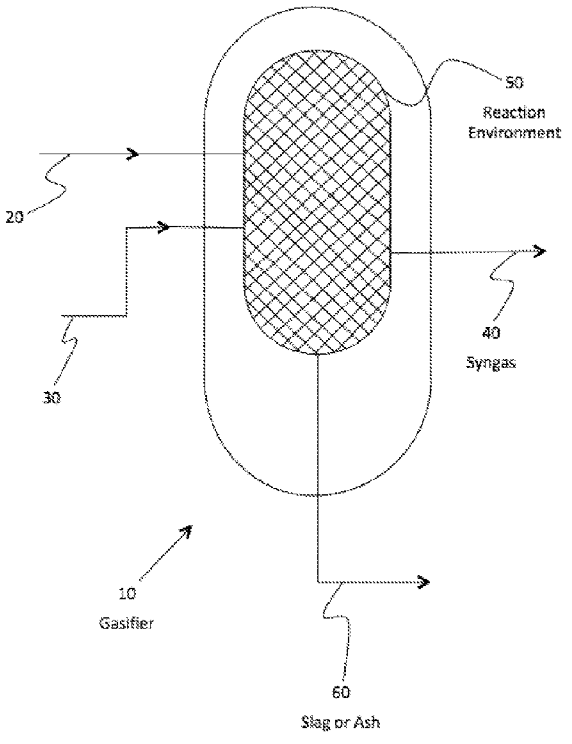
[Continued on next page]

(54) Title: GASIFIER FOR GENERATION OF SYNTHESIS GAS

FIG 3



(57) **Abstract**: The application provides a method and a gasifier for generating synthesis gas from a molten metal gasifier having a melt disposed within the gasifier, the melt comprising a molten metal. Feedstock is reduced in size size to yield an intermediate feed material with a firs predetermined size range at a first remote site. The intermediate feed material is processed to a reduced size feed fuel with a second pre-determined size rage at a second remote site, the second remote site being physically separate from the first remote site. The reduced size feed fuel and an oxidant gas is brought into fluid contact with the melt, the melt having a temperature of at least 700 degrees Celsius, to generate synthesis gas from at least a portion of the reduced size feed fuel.

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Gasifier for generation of synthesis gas

Feedstock is supplied into a primary size reduction unit to yield intermediate feed fuel material having a first approximate sieve size range, intermediate feed fuel material directed toward a secondary size reduction unit to yield a desired feed fuel having a second approximate sieve size range, the desired feed fuel is delivered into the reaction environment of a gasifier to generate synthesis gas.

Technical Field

Gasification is a known process whereby solid organic or biomass fuel is partially combusted to collect combustible gaseous fuels.

Examples of various gasifiers for solid biomass fuels are found in U.S. Pat. No. 4,531,462 to Payne; U.S. Pat. No. 4,848,249 to Lepori et al; U.S. Pat. No. 5,138,957 to Morey et al and U.S. Pat. No. 6,120,567 to Cordell et al.

Coal gasification has, for example, been actually utilized in a power plant integrated with coal gasification, etc, with being oxygen or highly oxygen-enriched air is supplied to a coal gasification plant as a gasifying agent. However, consumption of the generated electric power in an auxiliary facility including an oxygen plant for producing such a gasifying agent is highly energy intensive.

The gasification reaction typically involves delivering feed, free-oxygen-containing gas and any other materials to a gasification reactor which is also referred to as a "partial oxidation gasifier reactor" or simply a "reactor" or "gasifier." Because of the high temperatures utilized, the gasifier is lined with a refractory material designed to withstand the reaction temperature.

The feed and oxygen are intimately mixed and reacted in the gasifier to form syngas. While the reaction will occur over a wide range of temperatures, the reaction temperature which is utilized must be high enough to melt any metals which may be in the feed.

If the temperature is not high enough, the outlet of the reactor may become blocked with unmelted metals. On the other hand, the temperature must be low enough so that the refractory materials lining the reactor are not damaged.

One way of controlling the temperature of the reaction is by controlling the amount of oxygen which is mixed with and subsequently reacts with the feed. In this manner, if it is desired to increase the temperature of the reaction, then the amount of oxygen is increased. On the other hand, if it is desired to decrease and temperature of the reaction, then the amount of oxygen is decreased.

Conventionally, the oxygen to be utilized in the reaction travels via a pipe from an oxygen source to a compressor and then through a second pipe from the compressor to the gasifier. There is often a reservoir between the compressor and the gasifier. At the gasifier, the oxygen is introduced through a port at the upper end of the reactor to mix with the feed. Control of the amount of oxygen which enters the port is accomplished by using a valve at the port. When the valve is open, oxygen flows into reactor.

When it is necessary to slow the reaction and cool it, for instance, when the flow of feed has slowed, then the flow through the valve is reduced, i.e., the valve is moved to a reduced flow position.

In recent years electric utilities have been developing alternative technologies for power generation to meet the increased demands of society. One alternative technology that is of recent interest is referred to as the Integrated Coal Gasification Combined Cycle (IGCC).

In this type of facility, coal is converted into a liquid or gaseous fuel through gasification followed by combustion and expansion of the combusted gases In a turbine. Power is recovered from the turbine.

A significant advantage of an IGCC system Is that capacity can be added in stages which permits incremental capital expenditures for providing the additional power demands of society.

In that regard, business decisions become easier. Although the IGCC systems permits phasing in terms of providing additional capacity and makes decisions easier from a business perspective, it presents problems to the design engineer because of the inability to match performance and efficiency requirements in the IGCC system.

One of the earlier integrated IGCC systems Involved a cryogenic air-separation system and power turbine and is Swearingen U.S. Pat. No. 2,520,862. The air separation unit was of common design, e.g., it employed a liquefaction and dual column distillation system with the dual column distillation system having a higher pressure and lower pressure column.

Low purity, low pressure oxygen generated In the air separation unit was used for oxidizing the fuel with the resulting gases being expanded in the power turbine. To enhance efficiency of the power turbine, waste nitrogen-rich gas was taken from the higher pressure column and mixed with the compressed feed air for combustion.

Two problems were presented by this approach, the first being that it was impossible to independently set the pressures of the higher pressure column with that of the inlet pressure to the turbine to achieve an optimum operating efficiency for both the air separation unit and for the power turbine and, secondly, nitrogen separation in the lower pressure column was inefficient due to the lack of nitrogen reflux available for that column.

Coveney in U.S. Pat. No. 3,731,495 disclosed an IGCC comprising an integrated air separation unit and power system wherein the cryogenic air separation unit employed a conventional double-column distillation system.

In contrast to Swearingen, Coveney quenched combustion gases with a waste nitrogen-rich gas obtained from the lower-pressure column.

However, in that case, it was impossible to independently control the pressure in the lower pressure column and the pressure at the inlet to the power turbine. As a result it was impossible to operate the lower pressure column and the turbine at its optimum pressures.

Olszewski, et al. in U.S. Pat. No. 4,224,045 disclosed an improved process over the Coveney and Swearingen processes wherein an air separation unit was combined with a power generating cycle.

Air was compressed via a compressor with one portion being routed to the air separation unit and the other to the combustion zone. In order to nearly match the optimum operating pressures of the air separation unit with the optimum operating pressures of the power turbine cycle, waste nitrogen from the lower pressure column was boosted in pressure by means of an auxiliary compressor and then combined with the compressed feed air to the combustion unit or to an intermediate zone in the power turbine itself.

Through the use of the auxiliary nitrogen compressor there was an inherent ability to boost the nitrogen pressure to the combustion zone independent of operation of the air separation unit. By this process, Olszewski was able to more nearly match the optimum pressures for the air separation unit and power turbine systems selected.

One problem associated with each of the systems described above is that even though the air separation units were integrated into an IGCC power generating system, the processes were not truly integrated in the sense that the air separation unit and IGCC power system were able to operate at their optimum pressures independent of each other.

Although Olszewski reached a higher degree of independent operability than Coveney and Swearingen, the process scheme was only suited for those processes wherein air was taken from the air compression section of the gas turbine and used for the air feed to the air separation unit.

The air inlet pressure to the air separation unit could be varied by using either a turbo expander on the air inlet stream or a booster compressor. Although it was possible to obtain an optimum pressure in the air separation system in the Olszewski process, for example, each prior art process received a part or all of the feed for the air separation unit from the gas turbine compressor section.

However, the inlet pressure to the Olszewski air separation unit required a lower-pressure rectification stage having a pressure of at least 20 psi lower than the optimum ignition pressure in the combustion zone.

In many cases enhanced operating efficiencies of the lower pressure column in the air separation unit may require a higher operating pressure than available in Olszewski, et al., particularly when moderate pressure nitrogen is desired.

None of these patents however describe suitably efficient means for preparing the biomass materials to be gasified.

A common problem for instance, is that the biomass materials are not prepared in a sufficiently contained area to prevent discharging of odours into the surrounding environment.

Further inefficiencies arise when the biomass material is not prepared, gasified and subsequently completely combusted in a single environment with appropriate feedback and interaction between the various stages of the process.

In U.S. Pat. No. 4,959,080 a coal gasification process is described which may be performed in a gasification reactor as above. This publication describes that a layer of slag will form on the membrane wall during gasification of coal. This layer of slag will flow downwards along the inner side of the membrane wall.

The Shell Coal Gasification Process also makes use of a gasification reactor comprising a pressure shell and a membrane walled reaction zone according to " Gasification" by Christofer Higman and Maarten van der Burgt, 2003, Elsevier Science, Burlington Mass., pages 118-120.

According to this publication the Shell Coal Gasification Process is typically performed at 1500° C. and at a pressure of between 30 and 40 bar. The horizontal burners are placed in small niches according to this publication.

In the Shell Coal Gasification Process at the lower end of the above disclosed pressure range. It is however desirable to operate a gasification reactor at higher pressures because, for example, the size of the reactor (diameter and/or length) can then be reduced while achieving the same capacity.

A reduced diameter of the gasification reactor provides a smaller circumferential area for the slag running down the vertical membrane wall. At an equal reactor throughput the thickness of the fluid slag layer is increased thereby.

This effect is even bigger by using high-ash feeds. It has been found that with increasing gas pressures and reduced reactor diameter, slag ingresses into the burner muffles. This slag deflects the oxygen/coal flame towards the metallic muffle walls, which causes extremely high heat fluxes. In combination with the higher overall surface temperatures steam blankets can be formed on the water cooling side, resulting in that locally no adequate cooling exists.

This in turn may result in that at such locations the metal of the membrane wall melts away.

U.S. Pat. No. 4,818,252 describes a burner muffle as present in a membrane wall of a gasification reactor. The burner muffle itself can be adapted in design depending on the gasification conditions.

The design comprises a vertical cooled shield comprised of interconnected concentric tubes around an opening for a gasification burner. This vertical concentric shield can be placed at different horizontal positions, i.e. closer to or further away from the membrane wall.

The burner muffle of U.S. Pat. No. 4,818,252 is however vulnerable to slag ingress, when the gasification reaction is conducted under conditions wherein a thick layer of viscous liquid slag forms on the inside of the membrane wall. In such a situation the slag will flow in front of the burner head and disturb the combustion.

U.S. Pat. No. 4,818,252 discloses a slag deflector in FIG. 14 to avoid that slag covers the burner head. However, this design is not adequate to cope with thick layers of slag.

During pressure gasification of ash-containing feeds in dust form, in lumps or in liquid form, solid residues are formed from the feed ash as a function of the gasification temperature, said residues being formed either in the form of slightly molten granulated ash or in the form of fully molten slag and being evacuated from the pressure systems after cooling.

Feed in dust form, in lumps or in liquid form is understood to refer to conventional feeds such as coals of various ranks, cokes of various origin, but also to solids-containing oils and tars as well as slurries that may be utilized as coal-water or coal-oil slurries or slurries obtained in the form of suspensions of pyrolysis coke and pyrolysis liquids from thermal pre-treatment using different pyrolysis methods of biomass.

Generally, the granulated ash or fully molten slag is cooled by injecting water and is collected in bulk form in a water bath, discharged from the pressure system through pressure lock hoppers and disposed of, or processed, into building materials.

Such type methods and apparatus are described in European Patent No. EP 0 545 241 B1 and German Patent No. DE 4 109 231. EP 0 545 241 B1 describes a method for thermal utilization of waste materials, combining actually known process steps such as pyrolysis, comminution, classification, gasification and gas purification in which CO and H2 containing gas and a slag are formed in a gasification reactor, the slag granulating upon contact with water and being discharged from the gasification reactor.

DE 4 109 231 C2 describes a method of recycling halogen-loaded, carbon-containing waste materials by which waste materials are converted in the entrained flow, according to the principle of partial oxidation, to a carbon monoxide and hydrogen-containing crude gas.

There is a water bath, in which the solidifying slag particles are received and discharged from the pressure reactor through a lock hopper, being disposed in the lower part of the reactor.

This technology has major disadvantages leading to operation failures and limiting the availability of the technology as a whole. Such failures are e.g., due to the solidification of the ashes/slags in the water bath, which is promoted by the solid substances forming in a wide range of grain sizes.

The solidification leads to the formation of bridges and blocks the evacuation process.

Definitions

Approximating language, as used herein throughout the specification and claims, may be applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as "about," is not limited to the precise value specified. In some instances, the approximating language may correspond to the precision of an instrument for measuring the value. In some instances, the term about can denote a value within a range of ±10% of the quoted value.

Terms "heating value," "calorific value," "caloric value," are interchangeably used within this description.

"Feed", "feed fuel", "feedstock", as used herein throughout the specification and claims, may refer to coal, biomass, municipal solid waste, refuse-derived fuel (RDF), industrial waste, sewage, raw sewage, peat, scrap rubber, shale ore, tar sands, crude oil, natural gas, low-BTU blast furnace off-gas, flue gas exhaust, or a combination thereof.

Refuse-derived fuel (RDF), which is generally produced by shredding municipal solid waste, consists largely of organic components of municipal waste such as plastics and biodegradable waste. Non-combustible materials such as glass and metals are removed mechanically and the resultant material compressed into pellets, bricks, or logs and used for conversion to combustible gas, which can itself be used for electricity generation or the like.

Feed fuel material, feedstocks, can also mean agricultural feedstocks, forestry-based feedstocks, municipal solid waste (MSW), MSW can include the following: selected from the group consisting of waste plastics, used tires, paper, scrap-wood, food-processing waste, sewage, sludge, green-waste.

Feed fuel material, feedstocks can also mean fossil material such as crude oil, tar sands, shale oil, coal, natural gas, and combinations thereof.

Feed fuel material, feedstocks can also mean coal mine tailings, coal waste, coal fines, coal-water slurry, coal-liquid mixtures, and combinations thereof.

Feed fuel material, feedstocks can also mean refinery residual material comprises low-value carbonaceous by-products selected from the group consisting of asphaltenes, tars, and combinations thereof.

Flue gas exhaust also refers to gas containing CO, CO.sub.2 (carbon dioxide), nitrogen, nitrogen oxides and other particulates, sulphur compounds, soot, tar, or combustion exhaust gases generated from fossil-fuel power plants such as oil, coal, gas-fired powerplants, boilers, steam generators, combustion burners, gas turbine exhausts, reciprocating engine exhaust gases.

Fischer-Tropsch ("F-T") products, include refinery/petrochemical feedstocks, transportation fuels, synthetic crude oil, liquid fuels, lubricants, alpha olefins, waxes, and the like. The F-T reaction can be carried out in any type reactor, for example, through the use of fixed beds; moving beds; fluidized beds; slurries; bubbling beds, or any combination thereof. The F-T reaction can employ one or more catalysts including, but not limited to, copper-based; ruthenium-based; iron-based; cobalt-based; mixtures thereof, or any combination thereof. The F-T reaction can be carried out at temperatures ranging from about 190° C. (374° F.) to about 450° C. (842° F.) depending on the reactor configuration. Additional reaction and catalyst details can be found in U.S. 2005/0284797 and U.S. Pat. Nos. 5,621,155; 6,682,711; 6,331,575; 6,313,062; 6,284, 807; 6,136,868; 4,568663; 4,663,305; 5,348,982; 6,319,960; 6,124,367; 6,087,405; 5,945,459; 4,992,406; 6,117,814; 5,545,674, and 6,300,268.

Fischer-Tropsch products including liquids which can be further reacted and/or upgraded to a variety of finished hydrocarbon products. Certain products, e.g. C4-C5 hydrocarbons, can include high quality paraffin solvents which, if desired, can be hydrotreated to remove olefinic impurities, or employed without hydrotreating to produce a wide variety of wax products. Liquid hydrocarbon products, containing C16 and higher hydrocarbons can be upgraded by various hydroconversion reactions, for example, hydrocracking, hydroisomerization, catalytic dewaxing, isodewaxing, or combinations thereof. The converted C16 and higher hydrocarbons can be used in the production of mid-distillates, diesel fuel, jet fuel, isoparaffinic solvents, lubricants, drilling oils suitable for use in drilling muds, technical and medicinal grade white oil, chemical raw materials, and various hydrocarbon specialty products.

Commodity chemicals including, but not limited to, acetic acid, phosgene, isocyanates, formic acid, propionic acid, mixtures thereof, derivatives thereof, and/or combinations thereof, ammonia, using the Haber-Bosch process described in LeBlanc et al in "Ammonia," Kirk-Othmer Encyclopedia of Chemical Technology, Volume 2, 3rd Edition, 1978, pp., 494-500. In one or more embodiments, synthesis gas, or commodity chemicals or F-T products or a combination thereof can be used for the production of alkyl-formates, for example, the production of methyl formate. Any of several alkyl-formate production processes can be used, for example a gas or liquid phase reaction between carbon monoxide and methanol occurring in the presence of an alkaline, or alkaline earth metal methoxide catalyst. Additional details can be found in U.S. Pat. Nos. 3,716,619; 3,816,513; and 4,216,339.

In one or more embodiments, a reaction device can be used to produce methanol, dimethyl ether, ammonia, acetic anhydride, acetic acid, methyl acetate, acetate esters, vinyl acetate and polymers, ketenes, formaldehyde, dimethyl ether, olefins, derivatives thereof, or combinations thereof. For methanol production, for example, the Liquid Phase Methanol Process can be used (LPMEOH™). In this process, at least a portion of the carbon monoxide in the syngas can be directly converted into methanol using a slurry bubble column reactor and catalyst in an inert hydrocarbon oil reaction medium. The inert hydrocarbon oil reaction medium can conserve heat of reaction while idling during off-peak periods for a substantial amount of time while maintaining good catalyst activity.

Additional details can be found in U.S. 2006/0149423 and prior published Heydorn, E. C., Street, B. T., and Kornosky, R. M., "Liquid Phase Methanol (LPMEOH™) Project Operational Experience," (Presented at the Gasification Technology Council Meeting in San Francisco on Oct. 4-7, 1998). Gas phase processes for producing methanol can also be used. For example, known processes using copper based catalysts, the Imperial Chemical Industries process, the Lurgi process and the Mitsubishi process can be used.

In one or more embodiments, the hydrogen-rich product can be used in one or more downstream operations, including, but not limited to, hydrogenation processes, fuel cell energy processes, ammonia production, and/or hydrogen fuel. For example, the hydrogen-rich product can be used to make hydrogen fuel using one or more hydrogen fuel cells. In one or more embodiments, at least a portion of the syngas can be combined with one or more oxidants and combusted in one or more combustors to provide a high pressure/high temperature exhaust gas.

The exhaust gas can be passed through one or more turbines and/or heat recovery devices to provide mechanical power, electrical power and/or steam. In one or more embodiments, the exhaust gas can be introduced to one or more gas turbines to provide an exhaust gas and mechanical shaft power to drive the one or more electric generators. In one or more embodiments, the exhaust gas can be introduced to one or more heat recovery systems to provide steam. In one or more embodiments, a first portion of the steam can be introduced to one or more steam turbines to provide mechanical shaft power to drive one or more electric generators. In one or more embodiments, a second portion of the steam can be introduced to the gasifier, and/or other auxiliary process equipment. In one or more embodiments, lower pressure steam from the one or more steam turbines can be recycled to the one or more heat recovery systems. In one or more embodiments, residual heat can be rejected to a condensation system well known to those skilled in the art or sold to local industrial and/or commercial steam consumers.

In one or more embodiments, the heat recovery system can be a closed-loop heating system, e.g. a waste heat boiler, shell-tube heat exchanger, and the like, capable of exchanging heat between the exhaust gas and the lower pressure steam to produce steam. In one or more embodiments, the heat recovery system can provide up to 17,350 kPa (2,500 psig), 855° C. (1,570° F.) superheated steam without supplemental fuel.

Coal refers to a common fossil fuel, the most common classification is based on the calorific value and composition of the coal.

Coal is of importance as a fuel for power generation now and in the future since there are a lot of coal reserves, and the coal reserves are hardly unevenly distributed over the world.

ASTM (American Society for Testing and Materials) standard D388 classifies the coals by rank. This is based on properties such as fixed carbon content, volatile matter content, calorific value and agglomerating character.

Broadly, the coals can be categorized as "high rank coal" and "low rank coal," which denote high-heating-value, lower ash content and lower heating value, higher ash content coals, respectively.

Low-rank coals include lignite and sub-bituminous coals. These coals have lower energy content and higher moisture levels.

High-rank coals, including bituminous and anthracite coals, contain more carbon than lower-rank coals and correspondingly have a much higher energy content. Some coals with intermediate properties may be termed as "medium rank coal."

The term biomass covers a broad range of materials that offer themselves as fuels or raw materials and are characterized by the fact that they are derived from recently living organisms (plants and animals).

This definition clearly excludes traditional fossil fuels, since although they are also derived from plant (coal) or animal (oil and gas) life, it has taken millions of years to convert them to their current form.

Thus the term biomass includes feeds derived from material such as wood, woodchips, sawdust, bark, seeds, straw, grass, and the like, from naturally occurring plants or purpose grown energy crops.

It includes agricultural and forestry wastes. Agricultural residue and energy crops may further include husks such as rice husk, coffee husk etc., maize, corn stover, oilseeds, cellulosic fibers like coconut, jute, and the like.

Agricultural residue also includes material obtained from agro-processing industries such as deoiled residue, gums from oil processing industry, bagasse from sugar processing industry, cotton gin trash and the like. It also includes other wastes from such industries such as coconut shell, almond shell, walnut shell, sunflower shell, and the like.

In addition to these wastes from agro industries, biomass may also include wastes from animals and humans.

In some embodiments, the biomass includes municipal waste or yard waste, sewage sludge and the like. In some other embodiments, the term biomass includes animal farming byproducts such as piggery waste or chicken litter. The term biomass may also include algae, microalgae, and the like.

Thus, biomass covers a wide range of material, characterized by the fact that they are derived from recently living plants and animals. All of these types of biomass contain carbon, hydrogen and oxygen, similar to many hydrocarbon fuels; thus the biomass can be used to generate energy.

As discussed in a previous section, biomass includes components such as oxygen, moisture and ash and the proportion of these depends on the type and source of the biomass used.

Due to presence of these components, the gasification characteristics of biomass are much different than that of coal. Due the presence of these components that do not add to heating value, the calorific vale of biomass is much lower than that of coal. The calorific value and composition of biomass also depend on other factors such as seasonal and geographical variability.

Additional Definitions

An "oil refinery," as defined herein, generally refers to an oil refinery, or aspects thereof, where crude oil (or other fossil fuels such as coal or natural gas) is processed. Processes carried out at such refineries include, but are not limited to, reforming, cracking, distilling, and the like.

"Refinery residual," or "refinery resid," as defined herein, generally refers to the heaviest by-product fractions produced at a refinery. Asphaltenes are a type of refinery resid, as is coker coke.

A "gasifier," as defined herein, refers to a reaction environment wherein a carbon carrying feedstock material is converted into a gas through the action of heat and, possibly, one or more reactive gases such as oxygen, air, carbon dioxide (CO2), and/or steam. Gasifier can mean partial oxidation gasifier, a steam reformer, an autothermal reformer, and combinations thereof. Gasifier can mean a downdraft type gasifier, a cross-draft type gasifier, a fluidized bed type gasifier (or fluid bed), a moving bed type gasifier, a entrained flow type gasifier, a molten bed type gasifier, and combinations thereof. A molten bed type gasifier means a gasifier having a melt, molten metal, molten metal alloy, liquid akali-metal, or combinations as at least a port of the reaction environment, and such melt being disposed within or in proximity to the gasifier, feed delivered into fluid contact with the melt to cause at least a portion of the feed to be converted into syngas.

"Synthesis gas," or "syngas," as defined herein, generally refers to a mixture of carbon monoxide (CO) and hydrogen (H2) produced by gasification in a gasifier.

Gasification Background

Gasification involves a number of reactions such as oxidation reactions,

$C+½O2→CO$

$CO+½O2→CO2$

$H2+½O2→H2O$

the Boudouard reaction,

$C+CO2\leftrightarrow 2CO$

the water gas or steam gasification reaction,

$C+H_2O \rightarrow CO+H_2$

the water-gas shift reaction,

$CO+H_2O \rightarrow CO_2+H_2$

and methanation reaction

$C+2H_2 \rightarrow CH_4$

Fuel, residual and waste materials are to be understood as meaning those with or without an ash content, such as brown or hard coals and their cokes, water/coal suspensions, but also oils, tars and slurries, as well as residues or wastes from chemical and wood pulping processes from the papermaking and pulp industry, such as for example black liquor from the Kraft process, as well as solid and liquid fractions from the waste management and recycling industry, such as used oils, PCB-containing oils, plastic and domestic refuse fractions or their processing products, and residual and waste materials from the chemical industry, such as for example nitrogen- and halogen-containing hydrocarbons or alkali metal salts of organic acids.

The autothermal entrained-bed gasification of solid, liquid and gaseous fuel materials has been known for many years in the field of gas generation.

The ratio of fuel material to oxygen-containing gasification agents is selected in such a way that, for reasons of quality of the synthesis gas, higher carbon compounds are cleaved completely to form synthesis-gas components, such as CO and H_2 , and the inorganic constituents are discharged in the form of molten liquid slag (J. Carl, P. Fritz, NOELL-KONVERSIONSVERFAHREN [NOELL CONVERSION PROCESS], EF-Verlag für Energie-und Umwelttechnik GmbH 1996, p. 33 and p. 73).

Using various systems which have gained acceptance in the prior art, gasification gas and the molten liquid inorganic fraction, e.g. slag, can be discharged from the reaction chamber of the gasification appliance separately or together (DE 19718131.7).

Both systems which are provided with a refractory lining and cooled systems have been introduced for internally delimiting the contour of the reaction chamber of the gasification system (DE 4446803 A1).

Gasification systems which are provided with a refractory lining have the advantage of low heat losses and therefore offer an energy-efficient conversion of the fuel materials supplied.

However, they can only be used for ash-free fuel materials, since the liquid slag which flows off the inner surface of the reaction chamber during the entrained-bed gasification dissolves the refractory lining and therefore only allows very limited operating times to be achieved before an expensive refit is required.

Various fuel and waste materials, such as for example heavy-metal- or light-ash-containing oils, tars or tar-oil solid slurries contain too little ash to form a sufficiently protective layer of slag with cooled reactor walls, resulting in additional energy losses, yet on the other hand the ash content is too high to prevent the refractory layer from melting away or being dissolved if reactors with a refractory lining were to be used and to allow sufficiently long operating times to be achieved before a refit is required.

A further drawback is the complicated structure of the reactor wall, which may lead to considerable problems during production and in operation. For example, the reactor wall of the entrained-bed gasifier shown in J. Carl, P. Fritz: NOELL-KONVERSIONSVERFAHREN [NOELL CONVERSION PROCESS], EF-Verlag für Energie- und Umwelttechnik GmbH, Berlin 1996, p. 33 and p. 73 comprises an unpressurized water shell, the pressure shell, which is protected against corrosion inside with a tar/epoxy resin mixture and is lined with lightweight refractory concrete, and the cooling screen which, in the same way as a diaphragm wall which is conventionally used in the construction of boilers, comprises cooling tubes which are welded together in a gas tight manner, through which water flows, which are pinned and which are lined with a thin layer of SiC. Between the cooling screen and the pressure shell, which is lined with refractory concrete, there is a cooling-screen gap which has to be purged with a dry oxygen-free gas in order to avoid backflows and condensate formation.

To eliminate the above drawbacks, DE 198 29 385 C1 has disclosed an appliance in which a cooling gap was arranged inside the pressure shell of the gasification reactor, which gap is delimited by a cooled wall provided with ceramic material or a layer of slag in the direction toward the reaction chamber.

This appliance has the advantage of representing a simple technical solution with regard to the reactor design.

The drawback is that only limited pressure differences between the reaction chamber and the cooling gap are possible, leading to a considerable outlay on control and safety engineering.

For example, in the event of pressure fluctuations in the reaction chamber or during start-up and run-down processes, the pressure in the cooling gap has to be constantly adapted to the pressure in the reaction chamber.

This may cause problems in the event of rapid depressurization of the reaction chamber for safety engineering reasons, since the pressure in the cooling gap cannot be adapted as quickly, and this may lead to mechanical destruction of the cooling shell.

DD 226 588 A1 has disclosed a pinned screen for heating installations in which the pins are designed as spacers between pressure shell or pressure shell and inner skin. However, this screen cannot be used to good effect if the ash contents in the fuel and waste materials differ.

Summary of the invention

Feedstock is supplied into a primary size reduction unit to yield intermediate feed fuel material having a first approximate sieve size range, intermediate feed fuel material directed toward a secondary size reduction unit to yield a desired feed fuel having a second approximate sieve size range, the desired feed fuel is delivered into the reaction environment of a gasifier to generate synthesis gas.

It is found that in some gasifiers having the capability to accept and convert more than one feed type into syngas, that the proximate particle size of the feed is significant to the conversion efficiency and feed conversion rate.

In the case of such gasifiers having a multiple feed capability, the inherent sizes and density of each feed type may vary, for instance, coal versus RDF. As such, in some cases, certain feeds may require more than one pass through a size reduction stage through a suitable size reduction device such as a shredder, a milling plant, or a combination.

Specifically, in the case of molten bed gasifiers requiring multiple feed capability and high feed conversion rates, there is an optimal proximate particle size range that can only be suitably achieved in at least two size reduction stages or more.

Usually, this multiple size reduction steps have to be performed in multiple remote sites. It should be noted that a first remote site may be in proximity to the second remote site or that they may be arranged in a singular housing enclosure, they are still considered as separate remote sites since finished feed from the first remote site may be delivered and transported to the second remote site by means of a transport media such as a mechanical belt drive or by action of gravity.

It has been found that for molten bed gasification to be performed with multiple feed capability and having high feed conversion efficiency, the proximate particle size of the feed has to be reduced in at least two steps and a use of either oxidant gas (such as oxygen) or a liquid mixture (slurry) contributes to the optimal operation of the molten bed gasifier.

In other cases, certain feed types may require successive shredding or milling to achieve a desired proximate particle size, for example, shredding wood waste into 15 mm (millimeters) is generally possible with a single stage shredding system, but MSW (municipal solid waste) cannot be reduced to 15 mm unless a combination of equipment each configured uniquely as MSW feed is highly variable in material composition.

The subject of the present specification is now explained in further detail with respect to the following Figures, in which

Fig. 1 shows a first gasifier,

Fig. 2 shows a second gasifier comprising an exhaust gas scrubber, an exhaust gas accumulator and an exhaust gas consumer,

Fig. 3 shows a schematic drawing of a portion of a gasifier according to Fig. 1 or Fig. 2,

Fig. 4 shows a first gasification method having two feed particle size reduction stages and a preparation of a slurry or an entrained gas mixture,

Fig. 5 shows a second gasification method having two feed particle size reduction stages and a preparation of a slurry mixture,

Fig. 6 shows a third gasification method having two feed particle size reduction stages and a preparation of a feed and oxidant gas mixture,

Fig. 7 shows a fourth gasification method having two feed particle size reduction stages and a preparation of mixture with a slurry fluid,

Fig. 8 shows a fifth gasification method having one feed particle size reduction stage, and preparation of a mixture with a slurry fluid and/or oxidant gas,

Fig. 9 shows a first proximate particle size distribution after a first size reduction stage,

Fig. 10 shows a second proximate particle size distribution after a first size reduction stage.

Generalized Process Example "A"

A multiplicity of feedstock is mixed into a feedstream and delivered to a primary remote site to be reduced in proximate size to yield an intermediate feed material having a proximate particle size range of about between 100 to 30 millimeters.

The intermediate feed material is processed in a secondary size reduction remote site to yield desired feed fuel having a proximate particle size range of about between 30 to 0.3 millimeters (mm).

With reference to FIG. 4, feed 10 is first processed in a remote site 20 to generate a feed stream intermediate having a proximate particle feed size of between 100 mm to 10 mm, and the intermediate feed stream is then processed in a second step at remote site 30 to produce a finished feed product having a proximate particle feed size of about between 10 mm to 0.01 mm. Remote site 20 and 30 may be physically separated, in the case of having different size reduction arrangement devices for processing of the first or second size reduction steps, or be configured to be within a single processing column or site arranged in series one after another.

Feed fuel from site 30 having a proximate particle size range of about between 30 mm to 0.3 mm, or about between 10 mm to 0.01 mm is delivered into the identified reaction environment 50 of FIG. 3 of at least one gasifier at an operating site for generating synthesis gas ("syngas") from at least a portion of the said feed fuel.

Generalized Process Example "B"

At least one identified feedstock is supplied as a first feedstream to be delivered to a primary remote site to be reduced in proximate size to yield an intermediate feed material having a proximate particle size range of about between 100 mm to 30 mm, and with reference to FIG. 4, intermediate feed from remote site 30 is prepared into a slurry 40 for delivery into the reaction environment 50 of gasifier 10 of FIG. 3 using a slurry mixer.

The intermediate feed material is then supplied as a second feedstream to be delivered to a secondary remote site to be reduced in proximate size to yield a reduced size feed having a proximate particle size range of about between 30 mm to 0.3 mm, the reduced size feed further mixed with a fluid or a liquid to form a slurry having a desired slurry viscosity, apparent viscosity, density, apparent density range.

The formed feed slurry is delivered into the identified reaction environment of at least one gasifier at an operating site for generating synthesis gas ("syngas") from at least a portion of the said formed feed slurry.

With reference to FIG. 5, a multiplicity of feed 10, feed 20, and feed 30, are subjected to size reduction in the first step of 40 to generate an intermediate feed having a proximate particle feed size of about between 100 mm to 10 mm.

The intermediate feed is then processed in a second step at site 50 to a proximate particle feed size of about between 10 mm to 0.01 mm to yield a finished feed. The finished feed is then formed into a slurry 70 at site 60 and delivered into a gasifier 80.

The mixing ratio of reduced size feed to fluid or liquid can range between the following ranges depending on the reaction environment parameter of the gasifier to which such a formed feed slurry will be delivered for syngas generation at an operating site, in various configurations the ranges are as follows:

Preferred Mixing Ratios ("Type 1")

(Reduced Size Feed to Fluid or Liquid)
(Alternatively the solids fraction percentage of the formed feed slurry)

1. 5 percent to 10 percent
2. 10 percent to 15 percent
3. 15 percent to 20 percent
4. 20 percent to 25 percent
5. 25 percent to 30 percent
6. 30 percent to 35 percent
7. 35 percent to 40 percent
8. 45 percent to 50 percent
9. 50 percent to 55 percent
10. 55 percent to 60 percent
11. 60 percent to 65 percent
12. 65 percent to 70 percent

Preferred Mixing Ratios ("Type 2")

(Fluid or Liquid to Reduced Size Feed)
(Alternatively the liquids fraction percentage of the formed feed slurry)

1. 10 percent to 15 percent
2. 15 percent to 20 percent
3. 20 percent to 25 percent
4. 25 percent to 30 percent
5. 30 percent to 35 percent

6. 35 percent to 40 percent
7. 45 percent to 50 percent
8. 50 percent to 55 percent
9. 55 percent to 60 percent
10. 60 percent to 65 percent
11. 65 percent to 70 percent

The above ratios in some technical fields may also be referred to as the solids to liquids fraction. In this embodiment, and for example, mixing range number 6. of "Table 1" (of between 30 percent to 35 percent), this can mean that the formed feed slurry comprises between 30 percent to 35 percent of the reduced size feed (which is the solids fraction) such as those listed in table "Type 1", in another variation of this embodiment, this can also mean that the formed feed slurry comprises between 30 percent to 35 percent of the fluid or liquid (which is the liquids fraction) such as those listed in table "Type 2".

In the case of "Type 2" and range number 10, for example, this means that between 60 percent to 65 percent of the formed feed slurry is of the fluid or liquid, or the fluid or liquid fraction percentage or the "liquid weight ratio".
particle si
In other embodiments and variations of table "Type 1" and "Type 2" percentage may in some cases be mass weight percent.

Generalized Process Example "C"

At least one identified feedstock is supplied as a first feedstream to be delivered to a primary remote site to be reduced in proximate size to yield an intermediate feed material having a proximate particle size range of about between 100 mm to 10 mm,

The intermediate feed material is then supplied as a second feedstream to be delivered to a secondary remote site to be reduced in proximate size to yield a reduced size feed having a proximate particle size range of about between 10 mm to 0.1 mm, the reduced size feed further mixed with a fluid oxidant gas to form an entrained solids-gas mixture having a desired superficial gas velocity.

The formed entrained solids-gas mixture is delivered into the identified reaction environment of at least one gasifier at an operating site for generating synthesis gas ("syngas") from at least a portion of the said formed entrained solids-gas mixture.

The mixing ratio of reduced size feed to fluid oxidant gas varies to the following table "Table OS":

1. 3 percent to 5 percent
2. 5 percent to 10 percent
3. 10 percent to 15 percent
4. 15 percent to 20 percent
5. 20 percent to 25 percent
6. 25 percent to 30 percent
7. 30 percent to 35 percent
8. 35 percent to 40 percent
9. 40 percent to 45 percent
10. 45 percent to 50 percent
11. 50 percent to 55 percent
12. 55 percent to 60 percent
13. 60 percent to 65 percent
14. 65 percent to 80 percent

The fluid oxidant gas is selected from: air, oxygen, enriched oxygen air.
In this embodiment and the above table "Table OS",

Range item number 1 shall mean 3 mass weight percent to 5 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 2 shall mean 5 mass weight percent to 10 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 3 shall mean 10 mass weight percent to 15 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 4 shall mean 15 mass weight percent to 20 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 5 shall mean 20 mass weight percent to 25 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 6 shall mean 25 mass weight percent to 30 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 7 shall mean 30 mass weight percent to 35 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 8 shall mean 35 mass weight percent to 40 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 9 shall mean 40 mass weight percent to 45 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 10 shall mean 45 mass weight percent to 50 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 11 shall mean 50 mass weight percent to 55 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 12 shall mean 55 mass weight percent to 60 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 13 shall mean 60 mass weight percent to 65 mass weight percent of reduced size feed in the formed entrained solids-gas mixture. Range item number 14 shall mean 65 mass weight percent to 80 mass weight percent of reduced size feed in the formed entrained solids-gas mixture.

In one other embodiment variation of generalized example "C", at least one identified feedstock is supplied as a first feedstream to be delivered to a primary remote site to be reduced in proximate size to yield an intermediate feed material having a proximate particle size range of about between 20 mm to 10 mm, the intermediate feed material is supplied as a second feedstream to be delivered to a secondary remote site to be reduced in proximate size to yield a reduced size feed having a proximate particle size range of about between 10 mm to 0.01 mm, the reduced size feed further mixed with a fluid oxidant gas to form an entrained solids-gas mixture having a desired superficial gas velocity.

The formed entrained solids-gas mixture is delivered into the identified reaction environment of at least one gasifier at an operating site for generating synthesis gas ("syngas") from at least a portion of the said formed entrained solids-gas mixture.

Generalized example of a melt gasifier deployed in accordance to Generalized Process Examples "A", "B" and "C":

Drawings

FIG. 1 and FIG. 2 is a schematic of a melt gasifier utilized in combination with Generalized Process Examples “A”, “B”, “C”, or combinations thereof.

FIG. 3 is a schematic of this invention depicting the gasifier.

FIG. 4 is a schematic illustrating a generalized example.

FIG. 5 is a schematic illustrating a generalized example of a range of reduced particle feed mixed at a desired range percentage with a fluid or a liquid to form a feed slurry.

FIG. 6 is a schematic illustrating a generalized example of a range of reduced particle feed mixed at a desired range percentage with a oxidant gas to form a entrained oxidant gas mixture.

Detailed Description of the Preferred Embodiment of the Present Invention

With reference to FIG. 3, a generalized example of a gasifier 10 is illustrated, the reaction environment 50 is indicated in a proximal region within a determined interior of the gasifier 10, feed is delivered into the reaction environment 50 via line 20, and in some gasifier configurations oxygen or a oxidant gas such as air is delivered into reaction environment 50 via line 30.

In certain types of gasifiers the reaction environment 50 is a molten metal (not shown), while in others the reaction environment 50 is a fluidized bed of silica, particles, liquid slag (such as plasma-equipped gasifiers).

The primary product crude syngas is collected from reaction environment 50 via line 40. By-products such as liquid slag, ash, or other materials are collected from line 60.

Feed delivered via line 20 can be a slurry, or a entrained gas mixture, “entrained gas mixture” means a oxidant gas such as air, oxygen, or a vapor such as steam at a determined flow velocity, flow pressure, carrying the feed.

In either slurry or entrained gas mixture form, the proximate size of the feed determines the energy required for delivery of the feed into reaction environment 50.

In reaction environments operating at absolute pressures of the range between 3 bar to 127 bars pressure absolute, the proximate feed particle size also determines the reaction kinetics and conversion efficiency within the gasifier 10.

Example 1 and use of Generalized Process Examples “A”, “B”, “C”, or in combination:

FIG. 1 shows a crucible 1, which during operation contains a molten iron melt 2. In FIG. 1, 3 represents slag floating on top of the molten iron melt. The crucible 1 is optionally designed to be tilted round an axis 4 for discharge of molten iron melt 2 through opening 5 in the event where crucible repair or inspection is required.

Carbon contained in one or more feed fuel material, oxidant gas such as air, oxygen, and slag-forming compounds are injected by means of conventional lances and/or injection pipes (not shown).

A two step feed reduction method is found to be the optimal method based on various feed delivery configuration for a wide range of gasifiers, such as feed delivery configuration involving preparing a feed fuel slurry, or a feed delivery configuration involving preparing a feed fuel entrained within a oxygen-carrying oxidant gas in an entrained flow mixer.

The two step feed reduction method may vary in one embodiment wherein the first feed size reduction of the feed fuel (or plurality of feed fuel) is passing through at least one mesh filtration stage to form a substantially homogenous proximate particle size range of the feed fuel after the first size reduction step.

Due to the variation in feed composition and characteristics such as varying calorific value of each different feeds, it is found that either one feed fuel or multiple feed fuel material is first reduced in proximate particle size to within a range of about between 100 to 30 mm.

In some types of gasifiers such a range should be about between 100 mm to 60 mm.

In some feed mixtures such a range should be about between 100 mm to 10 mm, while in some other feed mixtures having either a significant moisture content, about between 200 mm to 100 mm.

It should be noted that the feed prior to any processing may be larger in proximate size than 100mm, 200mm, or greater.

Once the feed mixture or feed fuel material is processed to within the above sizes, it can be handled in a second size reduction stage to further reduce the proximate particle size of the feed fuel to a range of about between 30 mm to 1 mm.

In some configurations with certain gasifiers the second proximate particle size of the feed fuel should be processed to a range of about between 20 mm to less than 1mm, such as the range of about between 20 mm to 0.1 mm, and in another range of about between 20 mm to 0.01 mm.

Yet in some other configurations the second proximate particle size of the feed fuel should be processed to a range of about between 10 mm to 0.01 mm.

In some gasifiers the feed mixture is introduced as a feed slurry, therefore requiring the slurry solids to liquids percentage or mixing ratio to be within a desired range so as to achieve a desired minimum slurry suspension velocity.

In the top of the crucible 1 there is an exhaust gas pipe 6 for the syngas produced, which is connected by a gas-tight coupling 7 to a device in the direction in which the syngas is transported. This device comprises a cooler ("heat recovery system"), generally represented by 8, which according to this embodiment comprises two conventional steam boilers 9,10.

The syngas produced is thus led through the pipe 6 and another pipe 11 to the first boiler 9. The gas is then led to the second of the two boilers, 10, and on to a discharge pipe 12.

The discharge pipe is provided with a regulating valve 13 for controlling and maintaining the pressure in the crucible and the cooler 8. The regulating valve 13 is of any suitable kind.

As the syngas in the outlet pipe 12 has a considerably lower temperature than before it reaches the cooler, e.g. a temperature of approximately 200° C. (392° F.) a conventional regulating valve and conventional pressure units may be used. It is thus possible to avoid the considerable difficulties that would arise if the pressure had to be adjusted on the hot side, i.e. in direct connection with the exhaust gas pipe 6 from the crucible, where the temperature of the exhaust syngas is approximately 800° C. to 1500° C.

As the pressure is adjusted after the cooler 8, this cooler is maintained under pressure and is thus designed to resist any increased pressure in the system. Dust that has been separated is discharged through valves 14,15 at the bottom of the dust separators 16,17.

As mentioned above it is desirable to be able to tap off slag 3 during operation, i.e. whilst the crucible 1 is pressurized. According to the invention there is a device for tapping slag for this purpose, which is also pressurized at a pressure corresponding to the pressure in the crucible. The device for tapping slag comprises a horizontal slag channel 18 at the same level as the desired slag height, leading to a descending slag channel 19. The channel 19 is connected to a granulator 20.

In the horizontal channel 18 there is a flooding valve comprising a gate 21 or a board of a suitable material which in its lower end position closes the slag channel between the crucible and the granulator 20 and which in its raised position opens the channel mentioned. The gate 21 is sealed to the walls of the slag channel by means of devices not shown.

When the level of the slag in the crucible reaches the level of the horizontal slag channel 18, the gate 21 will be pushed upwards and slag will run out of the crucible 1 down to the granulator 20. In order to equalize the pressure in the granulator 20 both at this stage and when granulated material is discharged through a valve 23 at the bottom of the granulator, a pressure equalizing pipe 24 which includes a regulating valve 25 is provided. This pipe 24 connects the granulator 20 with the above-mentioned pipe 11, which leads gas away from the crucible 1.

An apparatus according to the present invention must, of course, be adapted to the pressures at which it is to be used. Modifications of valves, seals, design of cooler and the like may be made without departing from the main concept of the invention, which is to pressurize both the crucible and the cooler as well as any other auxiliary equipment, for example the tapping devices for slag and molten iron.

Example 2 and use of Generalized Process Examples “A”, “B”, “C”, or in combination:

The apparatus shown in the drawing FIG. 2 comprises a substantially sealed and closed gasifier 1 shown diagrammatically and which is provided with a bottom-blowing air supply system represented at 2 for blowing the electrically conductive material (molten metal) 1a disposed within the crucible of gasifier 1 with an oxidant gas such as air, oxygen or a combination, which can be introduced through a pipe 2a. A pipe 2b can add other desirable components to the oxidant gas while a cooling-water line 2c provides water to jacket the blowing tubes of the blowing device generally represented at 2.

The level of the electrically conductive material (molten metal) 1a in the crucible can be controlled by a receptacle 1b connected to the gasifier 1 below the surface of the electrically conductive material (molten metal) and containing a quantity 1c of the molten metal. A stopper 1d controls transfer of the molten metal between the crucible and the receptacle 1d.

Gasifier 1 is provided with an exhaust gas stack generally represented at 3 and connected through the gasifier 1 by a gas pressure gate 3a preventing escape of gases from the gasifier under the desired pressure absolute at which the latter is operated. The feed fuel is introduced into the gasifier via a hopper 7 and a charging pressure gate 6 which can have a pair of valves 6a and 6b which can be alternately opened to admit the feed fuel from the hopper 6 to the space between the valves 6a and 6b whereupon valve 6a is closed and valve 6b is opened to permit the charge to enter the gasifier 1. To prevent escape of gas and to maintain the pressure in the gasifier 1, a pump 33 supplies gas under pressure via the valve 34 to the gate 6, the excess gas is vented at 35.

In some configurations of certain gasifiers, a slurried feed fuel delivery configuration is optimal, and various feed ranges are found to be suitable, for example, in one embodiment, the desired feed fuel proximate particle size is about between 10 mm to 0.1 mm, in some other embodiments the range is about between 1 mm to 0.01 mm.

Slurry fluid or liquid content or mass weight percentage is about between the range of 10 percent to 70 percent.

In other configurations, the slurry fluid or liquid content or mass weight percentage is about between the range of 20 percent to 60 percent.

The proximate particle size of the feed of about between 30 mm to 0.01 mm therefore can be suitable with slurry fluid or liquid content or pass weight percentages of about between 10 percent to 70 percent.

In configurations requiring the use of an oxidant gas such as air, oxygen, or oxygen-enriched air, it is found that the final proximate particle size is about between 10 mm to 0.01 mm, and in some other gasifier reaction environments the final proximate particle size is about between 3 mm to 0.01 mm, thus allowing the oxidant gas to entrain the feed fuel at a desired superficial gas velocity into fluid contact with the reaction environment of the gasifier.

Again, due to the flow rate of feed fuel delivered into certain types of gasifiers, and in instances where more than one feed fuel material type is introduced alongside the variance in individual feed fuel material type composition and characteristics such as individual material shear, a two step process as proposed in this publication is found to be favorable for preparing the feed fuel having its final (second step) proximate particle size to be in the form of a feed fuel slurry, or entrained feed fuel oxidant gas mixture.

It should also be noted that in some embodiments the first step and second step of size reduction are carried out in two remote sites, while in some embodiments, the first step and second step of size reduction are carried out successively in a single size reduction tower or plant.

Further, in either first or second step size reduction, each first or second step may comprise of a sequence of additional size reduction steps so as to cause the feed fuel material to be within the desired proximate particle size range within each first and second step.

For instance, if the first size reduction feed range is about between 100 mm to 10 mm, the first size reduction stage may be a single size reduction device, or be arranged with a multiplicity of size reduction devices to cause the "intermediate" feed fuel to be within the said range of between 100 mm to 10 mm.

In some embodiments, and in the event where multiple feed fuel types are deployed, then certain individual feed fuel material may be subjected to a larger number of size reduction "passes" through more size reduction devices within the first size reduction step (to obtain the range of about between 100 mm to 10 mm).

The exhaust gas stack 3 forms a duct provided with an initial scrubbing system represented diagrammatically at 4. More particularly, the stack is divided into a downwardly extending portion 4e and an upright portion 4f. The downwardly extending portion 4e is provided with a group of spaced apart spray nozzles 4a connected by a manifold 4c to a source 4g of the wash water.

In another portion of the stack or duct, i.e. the upright portion 4f of the stack, is provided another array of nozzles 4b connected to the manifold 4d which is supplied with the scrubbing water.

Downstream of the scrubbing unit 4 there is provided a regulating valve 12 in the form of an annular-gap washer 13. As described in the aforementioned publication, the annular-gap washer can include a cylindrical duct 12c which can be provided with still another scrubbing nozzle 12d and through which the gas is caused to flow. The cylindrical duct 12c terminates at its lower end in a nozzle 12e, the latter being of the convergent-divergent type, the divergent section receiving a generally conical body 12a which can be displaced on a rod 12f by a servomotor 12d to control the pressure.

An inlet 30 provided with a valve 30' can supply a second flow stream of syngas from a remote site such as a second gasifier (not shown) to the syngas in the duct 40 before the syngas gas enters the gas accumulator 11 via the connecting duct 10 and a pressure control valve 10a. The gas accumulator 11 can be formed with a flexible membrane 16a so that the compressed gas in the compartment 16, e.g. nitrogen, will not mix with the washed and scrubbed syngas from the crucible gasifier set.

A nitrogen source 17 connected by a pressure control valve 17a and a throttle valve 17b with the chamber 16 of the accumulator to pressurize the latter and drive the syngas to the energy utilization stage or downstream syngas unit. A duct 18 leads from the gas accumulator 11 and is provided with an inlet 31 having a valve 31' for second flow stream of syngas used to augment the heat value of the syngas. A valve 41 controls the quantity of the syngas which is bled to an expansion turbine driving the generator 23' in the manner described in the aforementioned publication. Second flow stream of syngas may be of similar chemical composition as the original syngas generated from gasifier 1 or may have its CO, H.sub.2 or both gas content adjusted prior to introduction to inlet 31. The syngas, can be introduced into a combustion chamber 20 to which air is supplied by a compressor 22 to facilitate combustion of the syngas in the combustion chamber. The compressor 22 is, in turn, driven by a gas turbine 21 powered by the high velocity gases emerging from the combustion chamber. An electrical generator 23 is coupled to the shafts of the turbine 21 (so as to be driven thereby) and the compressor 22. Both generators 23 and 23' can be connected to a single network.

From the aforegoing it will be apparent that the gasifier 1 of the present invention includes a crucible for holding molten metal and one or more induction coil supplied with an AC power waveform of a desired waveform frequency, with a device 2 for the blowing of fresh gas through the melt (bottom-blowing nozzles), a exhaust gas stack 3 and a washing device 4 for the crucible produced syngas.

According to the invention, however, the gasifier 1 is formed as a substantially sealed or closed reaction vessel with a gate 6 for introducing the feed fuel from the hopper 7. The gasifier crucible set is also provided with a slag-removal device represented generally at 8 and a melt recovery device represented generally at 9 to recover at least a portion of the electrically conductive material disposed within gasifier 1 crucible. The slag removal device

8 comprises an upright cylinder 8b communicating from above with the top of the duct 9b leading to the charge tap 9c which can be selectively blocked or unblocked whenever the electrically conductive material is to be recovered or tapping of the electric induction furnace is desirable for some other purpose. The slag separator consists of an upright vessel 8b in which a plug 8a is displaceable.

The system also includes a exhaust gas stack 3 having an integrated wet-washing or scrubbing installation and connected to the reaction vessel 5. A connecting duct 10 connects the scrubbing units to the gas accumulator 11. In the wet-washing or scrubbing units 4 and/or in the connecting duct between the scrubbing device 4 and the gas accumulator 11, there is provided at least one control valve 12 which enables the pressure to build up behind the valve and hence in the gasifier. It has already been mentioned that the scrubbing device 4 includes the annular-gap washer, e.g. of the aforementioned publication, serving simultaneously as the control valve 12.

The stack 13 is also useful when the gas supplied exceeds that which can be successively stored in the accumulator 11 in above or underground storage. The apparatus aspects of the present invention involve the provision of the gas accumulator 11 with a volume such that it is capable of storing the syngas generated over a determined time period.

The accumulator 11 stores the scrubbed syngas in force-transmitting relationship with a nitrogen cushion operated by the nitrogen storage source 17. The gas can be continuously withdrawn from the accumulator 11. The gas withdrawn from the accumulator 11 is fed via line 18 to the syngas downstream unit. In the syngas downstream unit, at least part of the syngas is burned, e.g. for recovery of energy in a boiler. Note that the term syngas downstream unit means a downstream set of equipment or plant or both.

The duct 18 is connected via a valve 41 with the expansion turbine 19 discharging into the atmosphere. When the expansion turbine 19 is driven, generator 23' is engaged. The syngas from the accumulator 11 can also be introduced into a combustion chamber 20. In the embodiment illustrated, the gas turbine 21 drives the axial compressor 22 which supplies compressed air to the combustion chamber 20. The combustion products driving the turbine 21 thus also operate a generator 23 connected thereto.

In another embodiment of the present invention, the exhaust gas is diverted from line 18 to a downstream syngas unit comprising a synthesis gas burner configured within a combustion furnace-boiler set (not shown) for combustion of the syngas and the generation of steam to drive a steam turbine coupled with a generator for electric power generation. In yet another embodiment of the present invention, syngas is diverted from line 18 to a gas turbine set for generation of electric power, the gas turbine exhaust is diverted to a steam-cycle turbine set for generation of electric power in a combined cycle power configuration. In yet another embodiment of the present invention the syngas from line 18 is fed into a suitable fuel cell device for direct generation of electric power.

Generalized Process – Feed Particle Calculation Example

Reaction scheme and modeling

Based on analysis of the global reaction parameter incorporating petcoke, coal, biomass feeds, the main reactions are hereby provided:

Feeds with high volatile content:

$CH_4 + 1/2\, O_2 \rightarrow CO + 2 H_2$

$CH_4 + H_2O \rightarrow CO + 3H_2$

Global rate limiting parameters:

$H_2 + 0.5\, O_2 \rightarrow H_2O$

$CO + H_2O \leftrightarrow CO_2 + H_2$

Dependence on temperature during gasification would provide the following reactions comprising:

$C(s) + 0.5O_2 (g) \rightarrow CO (g)$

$C(s) + H_2O (g) \rightarrow CO (g) + H_2 (g)$

$C(s) + CO_2 (g) \rightarrow 2CO (g)$

Therefore, typical gasification reactions of coal/biomass can be represented by the following equations:

$Coal \rightarrow Char(C)+CH_4 +H_2 +CO$ (1)

$C+O_2 \rightarrow CO_2$ (2)

$C+CO_2 \rightarrow 2 CO$ (3)

$C+H_2O \rightarrow H_2 +CO$ (4)

$CO+H_2O \rightarrow CO_2 +H_2$ (5)

The pyrolysis reaction (1) and the shift reaction (5) take place relatively rapidly and the combustion reaction (2) is completed in very short time. But the reactions (3) and (4) are slow in reaction rate compared with the rest of the reactions and take much time for gasification. Therefore the improvement in gasification efficiency depends on how to make the reactions (3) or (4) faster. The reaction rate in the reaction (3) or (4) is influenced by the reaction temperature, partial pressures of gasifying agents, properties of coal particles, etc. According to the gasification processes mentioned above, optimum conditions are not always employed, so that char is discharged from a gasifier.

Computational fluid dynamics (CFD) determination of the above reaction parameters are based on the following well-known conservation equations for mass and momentum, expressing mass conservation by;

$$\frac{\partial}{\partial t}(\rho_f)+\frac{\partial}{\partial x_j}(\rho_f U_j)=0 \tag{A}$$

and fluid momentum conservation by;

$$\frac{\partial}{\partial t}(\rho_f U_i)+\frac{\partial}{\partial x_j}(\rho_f U_j U_i)=-\frac{\partial}{\partial x_i}p+\frac{\partial}{\partial x_j}\tau_{ji}+\rho_f g_i \tag{B}$$

where ρ_f is fluid density, U_f is fluid velocity, p is fluid pressure, g is the specific gravity and τ_{ij} is the fluid stress tensor. When the fluid stress tensor τ_{ij} is known, such as for a Newtonian fluid, the single-phase flow can be predicted by numerical solution of (A) and (B).

In the various embodiments of this invention a mixture of steam, air/oxygen and biomass/coal/wood particles are approximated in the CFD numerical calculation as follows:

In one configuration, the feed in the form of crushed or pulverized particles are entrained within a carrier gas such as steam, oxygen, air, or a combination thereof into contact with the melt via at least one lance device/apparatus.

Based on the selected Eulerian representation of (the wood/biomass/coal particles dispersed in a fluid containing steam-vapor droplets), given by the equations (A) and (B).

The flow phase is represented as a continuous field.

Transport equations for the phases appear from volume averages of the fluid and particles in a control volume (within the gasification zone of the gasifier). For a gas-particle system typical transport equations that appear are for mass conservation:

$$\frac{\partial}{\partial t}(\rho_f \alpha_f)+\frac{\partial}{\partial x_j}(\rho_f \alpha_f U_j)=0 \tag{C}$$

and for fluid momentum:

$$\frac{\partial}{\partial t}\left(\rho_f \alpha_f U_i\right)+\frac{\partial}{\partial x_j}\left(\rho_f \alpha_f U_j U_i\right)=-\alpha_f \frac{\partial}{\partial x_i} p+\alpha_f \frac{\partial}{\partial x_j} \tau_{ji}+\rho_f \alpha_f g_i+\alpha_p \beta (V_i-U_i) \quad \text{(D)}$$

The volume fraction of fluid α_f and the inter-phase friction factor β (drag term) appear from the volume averages of (A) and (B).

For particle mass balance:

$$\frac{\partial}{\partial t}\left(\rho_p \alpha_p\right)+\frac{\partial}{\partial x_j}\left(\rho_p \alpha_p V_j\right)=0 \quad \text{(E)}$$

and for particle momentum:

$$\frac{\partial}{\partial t}\left(\rho_p \alpha_p V_i\right)+\frac{\partial}{\partial x_j}\left(\rho_p \alpha_p V_j V_i\right)=-\frac{\partial}{\partial x_i} p^s+\frac{\partial}{\partial x_j} \tau_{ji}^s+\rho_p \alpha_p g_i-\alpha_p \frac{\partial}{\partial x_i} p+\alpha_p \frac{\partial}{\partial x_j} \tau_{ji}+\alpha_p \beta (U_i-V_i)$$

(F)

α_p is the volume fraction of particles. Because of inter-particle collisions and momentum exchange due to collisions both the solids pressure p^s and the solid particle internal stress τ_{ji}^s is included in the equations.

The velocities are now averages from small control volumes and are no longer the instantaneous velocities given in the equations (A) and (B). In a swarm of large particles the fluid velocity close to the particle surface is very different from the volume-averaged velocity. However, the effects of the local variations will in practice only affect the interphase transfer terms such as drag and mass transfer.

In another reactor configuration, where the feed is injected into contact with the melt from below its surface by means of one or more conduits such as tuyeres, fluid dynamics would have to be expressed in the general form of:

$$\frac{d\Phi_{\mathrm{CM}}}{dt}=\frac{d}{dt}\int_{V_{\mathrm{CM}}(t)} \phi\, dV=\int_{V_{\mathrm{CV}}(t=t_0)} \frac{\partial \phi}{\partial t} dV+\int_{A_{\mathrm{CV}}(t=t_0)} \phi\left(\vec{v}-\vec{v}_{A_{\mathrm{CV}}}\right)\cdot \vec{n}\, dA \xrightarrow{V_{\mathrm{CV}} \neq f(t)} \int_{V_{\mathrm{CV}}} \frac{\partial \phi}{\partial t} dV+\int_{A_{\mathrm{CV}}} \phi \vec{v} \cdot \vec{n}\, dA$$

Note that F may be mass, momentum, or energy in a control mass CM, and

A continuity equation is the mass balance ($\mathrm{d}m_{\mathrm{CM}}/\mathrm{d}t=0$) for a d$V$ system;

$$\frac{\mathrm{D}\rho}{\mathrm{D}t}+\rho\nabla\cdot\vec{v}=0$$

The momentum equation is the linear-momentum balance ($d\left(m\vec{v}\right)_{\mathrm{CM}}/dt=\vec{F}=\vec{F}_V+\vec{F}_A$), applied to a d$V$ system; with $\phi=\rho\vec{v}$ we get from the generalized equation above, using the convective derivative:

$$\rho\frac{\mathrm{D}\vec{v}}{\mathrm{D}t}=\frac{\partial\left(\rho\vec{v}\right)}{\partial t}+\nabla\cdot\left(\rho\vec{v}\vec{v}\right)=\nabla\cdot\overline{\overline{\tau}}+\rho\vec{g}=-\nabla\left(p+\rho gz\right)+\nabla\cdot\overline{\overline{\tau}}'$$

where $\overline{\overline{\tau}}$ is the stress tensor (such that the force per unit area of normal vector $\vec{n}$ is $\vec{f}=\overline{\overline{\tau}}\cdot\vec{n}$), $\vec{g}$ is any volumetric force field (e.g. gravity), p is fluid pressure (one third of the trace of the stress tensor), and $\overline{\overline{\tau}}'$ the viscous component of the stress tensor.

The energy equation should be expressed as follows:

Energy balance ($d\left(me\right)_{\mathrm{CM}}/dt=\dot{Q}+\dot{W}$) for a d$V$ system; with $\phi=\rho e$:

$$\rho c_p\frac{\mathrm{D}T}{\mathrm{D}t}=-\nabla\cdot\vec{q}+\alpha TDp/Dt+\overline{\overline{\tau}}':\nabla\vec{v}$$

The above is expressed in terms of temperature of the melt.

In one embodiment of the present invention, is it discovered that a tuyere device having a six-sided wall surface configuration is advantageous in directing a feed slurry into contact with the melt disposed in the melt gasifier, due to the following:

In very general terms, the heat flux convection behavior in the tuyere is

$$\dot{q} \equiv h\left(T - T_{\infty}\right) = -k\nabla_{n}T$$

During an increase in internal thermal energy is due to heat transfer at a source connected to the tuyere, the energy balance for a fluid flow (of the feed) at constant pressure without phase changes and reactions is $\dot{Q} = \dot{m}c\Delta T$ (therefore the same thermal load can be transported by a high mass-flow-rate flow with small temperature jump, or by a low mass-flow-rate flow with high temperature jump.)

Thermal boundary at the wall can be represented by the following:

$$\dot{q} \equiv h\left(T - T_{\infty}\right) = -k\nabla_{n}T \quad \rightarrow \quad h\Delta T \approx k\frac{\Delta T}{L} \quad \rightarrow \quad Nu \equiv \frac{hL}{k}$$

Based on the above Nu number the momentum equation previously shown is expanded to:

$$\frac{\mathrm{D}\vec{v}}{\mathrm{D}t} = -\frac{\nabla p}{\rho} + \nu\nabla^{2}\vec{v} \quad \rightarrow \quad \frac{v}{t} + v\frac{v}{L} \approx \frac{p}{\rho L} + \nu\frac{v}{L^{2}} \quad \rightarrow \quad \frac{1}{Sr}\frac{v^{2}}{L} + \frac{v^{2}}{L} \approx \frac{p}{\rho L} + \frac{1}{Re}\frac{v^{2}}{L} \quad \text{with} \quad \begin{cases} Re \equiv \dfrac{vL}{\nu} \\ Sr \equiv \dfrac{vt}{L} \end{cases}$$

(note that $Nu \equiv \frac{hL}{k}$ is to derive the Nusselt number being the ratio of convective heat flux to conductive heat flux)

Depending on the viscosity of the feed slurry, wall surface characteristics and mass flow velocity, the hydrodynamic behavior of the slurry is generally represented in the following manner:

Feed slurry of the velocity profile:

$$\frac{u}{u_{\infty}} = 1 - \left(\frac{y}{\delta}\right)^{7}$$

and a friction coefficient of:

$$c_{\mathrm{f},x} = \frac{0.059}{Re_x^{1/5}},\ c_{\mathrm{f},L} = \frac{0.074}{Re_L^{1/5}} - \frac{1700}{Re_L^{1/2}}$$

This is calculated based on a turbulence range of between $0.5 \cdot 10^6 < Re_x > 10 \cdot 10^6$

The multiphase approach outlined above can be easily modified to suit the reactor (gasifier) operating pressure and the flow field fluid velocity (thus the gasification agent superficial gas velocity), providing a highly flexible and scalable means to perform gasification of the coal/biomass/wood particles in numerous gasifier configurations such as an entrained flow burner or a melt bath (molten iron) gasifier.

Fig. 7 shows a gasification method in which feed fuel particles are reduced to a proximate size range of between 100 mm and 30 mm in a first reduction stage and to a proximate particle size of between 30 mm and 0.3 mm. Before the reduced size feed particles are introduced in a reaction environment 50 they are mixed with a slurry fluid to obtain slurry-According to this embodiment, the slurry liquid amounts to about 5 to 70 weight per cent of the slurry.

Fig. 8 shows a gasification method in which feed fuel particles are reduced to a proximate size range of between 30 mm and 0.3 mm in a single reduction stage. Before the reduced size feed particles are introduced in a reaction environment 50 they are mixed with a slurry fluid and/or with an oxidant gas to obtain a mixture. According to this embodiment, the slurry liquid amounts to about 5 to 70 weight per cent of the mixture if a slurry liquid is provided.

Fig .9 shows a proximate size distribution for a reduction stage using a sieve or other type of size filter that produces a cut-off at larger sizes. In Figs. 9 and 10, a probability density is plotted over a particle size in mm. An approximation to the probability density can be obtained by making a large number of measurements and determining the number of particles in predetermined small size intervals, also referred to as "bins". The normalization is chosen such that the total surface under the curve adds up to the total probability of 1.

An upper limit of the size distribution, which is at 100 mm in the example of Fig. 9 is determined by a size cut-off. A lower limit 90 of the size distribution, which is at 10 mm in the example of Fig. 9, is determined by the minimum size r at which a probability to find a particle smaller or equal to this size is equal to a pre-determined value.

A median of the size distribution is marked by a dashed line. The median is defined as the size at which the surface under the curve left to the median size equals the surface under the curve left to the median size.

According to another definition, the vertical axis provides a mass density, or in other words, the contribution to the total mass of particles in a given small interval. According to this definition, the surface under the curve adds up to the total mass. The lower limit is then determined by the maximum size r at which the contribution of particles smaller or equal to the size r to the total mass is below a pre-determined value.

Fig. 10 shows a proximate size distribution for a reduction stage using no size filter or a type of size filter that produces a tapering off at larger sizes, such as a shaker, for example.

In the example of Fig. 10, the probability can be approximated by a Gaussian distribution which is cut off at a lower end and at a high end. In this case, a lower limit 92 of the size distribution can be defined as the lower a*sigma limit, wherein sigma is the standard deviation from the mean value and a is a predetermined constant. This means the lower limit is at the mean value minus a times the standard deviation of the Gaussian distribution.

Similarly, an upper size limit 93 can be defined as the mean size value plus a times the standard deviation. In the example of Fig. 10, the constant "a" is chosen equal to three.

A mean value 94, which is identical to the median for a symmetric distribution as the Gaussian distribution, has been symbolized by a dashed line.

Similar definitions for the lower and upper limit can be made if the distribution is approximately a mass density distribution having the shape of a cut off Gaussian distribution.

For a general probability density or a general mass density distribution, a lower limit can be defined as the minimum size below which the contribution to the total probability is equal to a pre-determined probability or, respectively, as the minimum size below which the contribution to the total mass is equal to a pre-determined mass fraction. Similarly, the lower limit can be defined as the maximum size above which the contribution to the total probability is equal to a pre-determined probability or, respectively, as the maximum size above which the contribution to the total mass is equal to a pre-determined mass fraction. This probability, or mass fraction can in particular be chosen as the total probability or mass fraction that is equivalent to the total probability or mass fraction outside the 3 sigma range, or in general, the a*sigma range of a Gaussian distribution. Similar definitions can be made without departing from the general idea of the above definitions provided for the lower and upper size limit.

Within the context of this specification, a size range between a lower limit and an upper limit is to be understood as a size ranged bounded by a lower limit and an upper limit according to the abovementioned definition or according to definitions which are similar to those mentioned above with respect to Figs 9 and 10. In particular, this may mean that there are particles that lie outside the specified range but that their contribution to a the total probability or their contribution to the total mass, as the case may be, is less than a pre-determined value. Typical values are 10%, 5%, 2% or less, for example. In particular, for a Gaussian distribution the probabilities for particles to have sizes above/below the 1 sigma, 2 sigma and 3 sigma deviations are about 15.8 %, 2.2 % and 0.1 %, respectively.

While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. The features described in various embodiments may be interchanged to form newer configurations. These features may be combined with already well-known configurations and operation strategies to achieve better performance. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

The embodiments can also be described with the following lists of elements being organized into items. The respective combinations of features which are disclosed in the item list are regarded as independent subject matter, respectively, that can also be combined with other features of the present specification.

1. A gasifier, comprising;

   one or more conduit in fluid communication with an identified reaction environment within gasifier for delivering a desired feed fuel into said reaction environment; and

   a gas flow outlet device in fluid communication with at least a portion of reaction environment for collecting and withdrawing a synthesis gas product flow stream from reaction environment.

2. The gasifier of claim 1 wherein a plurality of feedstock is processed in a first size reduction remote site plant to yield an intermediate feed material having a proximate particle size range of about between 100 millimeters to 10 millimeters, and intermediate feed material is processed in a second size reduction remote site plant to yield desired feed fuel having a proximate particle size range of about between 10 to 0.01 millimeters.

3. The gasifier of claim 1 wherein pressurized flow stream of an oxidant gas is selected from the group consisting of air, oxygen, oxygen enriched air.

4. A method for generating synthesis gas from a gasifier, comprising:

   (a) processing a plurality of feedstock by size reduction to yield an intermediate feed material having a proximate particle size range of about between 100 to 10 millimeters,

   (b) finishing intermediate feed material into a reduced size feed fuel by size reduction to yield desired feed fuel having proximate particle size range of about between 10 to 0.01 millimeters,

   (c) delivering the reduced size feed fuel from the step of (b), an oxidant gas, or a mixture, into fluid contact with a reaction environment having a temperature range of between

700 degrees Celsius to 1700 degrees Celsius to generate synthesis gas from at least a portion of the reduced size feed fuel.

5. A method for generating synthesis gas from a gasifier having a melt therein, comprising:

   (a) processing one or more feed material into a reduced size feed fuel by size reduction to yield a reduced size feed fuel having a proximate particle size range of about between 30 to 0.01 millimeters,

   (b) forming a feed fuel slurry by mixing the reduced size feed fuel with at least one fluid or liquid in a determined solids to liquid fraction ratio,

   (c) delivering the feed fuel slurry from the step of (b), an oxidant gas carrying oxygen gas, or a mixture, into fluid contact with the melt disposed within gasifier, the melt having a temperature range of between 700 degrees Celsius to 2000 degrees Celsius to generate synthesis gas from at least a portion of the reduced size feed fuel.

6. A molten metal gasifier, comprising:

   – a first size reduction remote site plant which is operable to process a plurality of feedstock by size reduction to yield an intermediate feed material having a proximate particle size range of about between 100 to 10 millimeters,

   - a second size reduction remote site plant which is operable to finish the intermediate feed material into a reduced size feed fuel by size reduction to yield a reduced size feed fuel having proximate particle size range of about between 10 to 0.01 millimeters,

   - an injection device for delivering the reduced size feed fuel from the step of (b), an oxidant gas, or a mixture, into fluid contact with a reaction environment,

   - a heating device for heating the reaction environment to a temperature range of between 700 degrees Celsius to 1700 degrees Celsius to generate synthesis gas from at least a portion of the reduced size feed fuel.

7. A molten metal gasifier, comprising:

– a size reduction remote site plant which is operable to process one or more feed material into a desired feed fuel by size reduction to yield desired feed fuel having a proximate particle size range of about between 30 to 0.01 millimeters,

- a mixer for forming a feed fuel slurry by mixing desired feed fuel with at least one fluid or liquid in a determined solids to liquid fraction ratio,

- an injection device for delivering the feed fuel slurry from the step of (b), an oxidant gas carrying oxygen gas, or a mixture, into fluid contact with melt disposed within gasifier,

- a heating device for heating the melt to a temperature range of between 700 degrees Celsius to 2000 degrees Celsius to generate synthesis gas from at least a portion of desired feed fuel.

8. The molten metal gasifier of one or more of items 1 - 7, comprising an induction coil for heating the melt, wherein the induction coil at least partially surrounds a reaction vessel of the gasifier.

The slurry from the reduced size feed fuel which is mentioned in the specification and the claims can be generated with almost any fluid or liquid, and especially from water, seawater, hydrocarbon-liquid, sewage water, brackage water, waste water, or a combination thereof.

CLAIMS:

1. A method for generating synthesis gas from a molten metal gasifier having a melt disposed within the gasifier, the melt comprising a molten metal, the method comprising:

   - processing a plurality of feedstock by size reduction to yield an intermediate feed material having a first pre-determined range of proximate particle sizes, wherein the processing of the plurality of feedstock is carried out at a first remote site,

   - finishing the intermediate feed material into a reduced size feed fuel by size reduction to yield a reduced size feed fuel having a second pre-determined range of proximate particle sizes, wherein the finishing of the intermediate feed material is carried out at a second remote site which is physically separate from the first remote site, and wherein the upper limit of the first pre-determined range of proximate particle sizes is larger than the upper limit of the second pre-determined range of proximate particle sizes,

   - delivering the reduced size feed fuel from the step of finishing into fluid contact with the melt, the melt having a temperature of at least 700 degrees Celsius to generate synthesis gas from at least a portion of the reduced size feed fuel.

2. The method according to claim 1, wherein the delivering of the reduced size feed fuel comprises
   - forming a feed fuel slurry by mixing a predetermined amount of the reduced size feed fuel with at least one fluid or liquid in a predetermined solids to fluid or solids to liquid fraction ratio.

3. The method according to claim 1, wherein the delivering of the reduced size feed fuel comprises
   - delivering an entrained feed fuel-slurry mixture into fluid contact with a melt disposed within the gasifier.

4. The method according to claim 3, wherein a slurry to fluid or liquid weight ratio is in a range of 10 to 70 percent.

5. The method according to claim 3, wherein a solids to fluid or liquid weight ratio of the slurry is at most 70 percent.

6. The method according to claim 3, wherein a solids to fluid or liquid weight ratio of the slurry is in a range of 20 to 60 percent.

7. The method according to claim 1 comprising passing the feed fuel through at least one mesh filtration stage after the first size reduction step to form a substantially homogeneous proximate particle size.

8. The method according to claim 1, wherein an upper limit of the size of the intermediate feed material is 100 mm.

9. The method according to claim 1, wherein the size range of the intermediate feed material after the first size reduction stage is between 100 to 10 mm.

10. The method according to claim 1, wherein the size range of the intermediate feed material after the first size reduction stage is between 100 to 30 mm.

11. The method according to claim 1, wherein the size range of the intermediate feed material after the first size reduction stage is between 100 to 60 mm.

12. The method according to claim 1, wherein an upper limit of the reduced size feed after the second size reduction stage is 10 mm.

13. The method according to claim 1, wherein the size range of the reduced size feed after the second size reduction stage is between 10 to 0.01 mm.

14. The method according to claim 1, wherein an upper limit of the reduced size feed after the second size reduction stage is 30 mm.

15. The method according to claim 1, wherein the size range of the reduced size feed after the second size reduction stage is between 30 to 0.3 mm.

16. The method according to claim 1, wherein a proximate temperature range of the melt is between 700 and 2000 degrees Celsius.

17. The method according to claim 1, wherein a proximate temperature range of the melt is between 700 and 1700 degrees Celsius.

18. The method according to claim 1, wherein the first size reduction stage of the feed comprises shredding or milling with a shredder, a milling plant, or a combination thereof.

19. A molten metal gasifier for gasifying a feed fuel using a melt disposed within the gasifier, the melt comprising a molten metal, comprising

a first size reduction remote site plant for obtaining an intermediate feed material from the feed fuel, the intermediate feed material having a first pre-determined size range,

a second size reduction remote site plant for obtaining a reduced size feed fuel having a second pre-determined size range, the second size reduction remote site plant being physically separate from the first size reduction remote site plant, and wherein the upper limit of the first pre-determined range of proximate particle sizes is larger than the upper limit of the second pre-determined range of proximate particle sizes,

one or more conduits in fluid communication with a reaction environment within the gasifier for delivering the reduced size feed fuel into said reaction environment; and

a gas flow outlet device in fluid communication with at least a portion of reaction environment for collecting and withdrawing a synthesis gas product flow stream from reaction environment.

20. The molten metal gasifier according to claim 19, wherein the first size reduction remote site plant is operable to reduce the size of the feed fuel to a size range between 100 and 10 mm.

21. The molten metal gasifier according to claim 19, wherein the first size reduction remote site plant is operable to reduce the size of the feed fuel to a size range between 100 and 30 mm.

22. The molten metal gasifier according to claim 19, wherein the second size reduction remote site plant is operable to reduce the size of the feed fuel to a size range between 10 and 0.1 mm.

23. The molten metal gasifier according to claim 19, wherein the second size reduction remote site plant is operable to reduce the size of the feed fuel to a size range between 30 and 0.3 mm.

24. The molten metal gasifier of claim 19, comprising a slurry mixer for generating a slurry from the reduced size feed fuel and a liquid, the slurry mixer being connected to an inlet of a reaction vessel of the gasifier.

25. The molten metal gasifier of claim 19, wherein the gasifier comprises a substantially sealed reaction vessel.

26. The molten metal gasifier of claim 19, wherein the gasifier comprises an inlet for feed fuel, the inlet comprising a hopper and at least one valve.

27. The molten metal gasifier of claim 19, comprising an entrained flow mixer for mixing the reduced size feed fuel with a fluid oxidant gas, the entrained flow mixer being connected to an inlet of a reaction vessel of the gasifier.

DRAWINGS:

FIG. 1

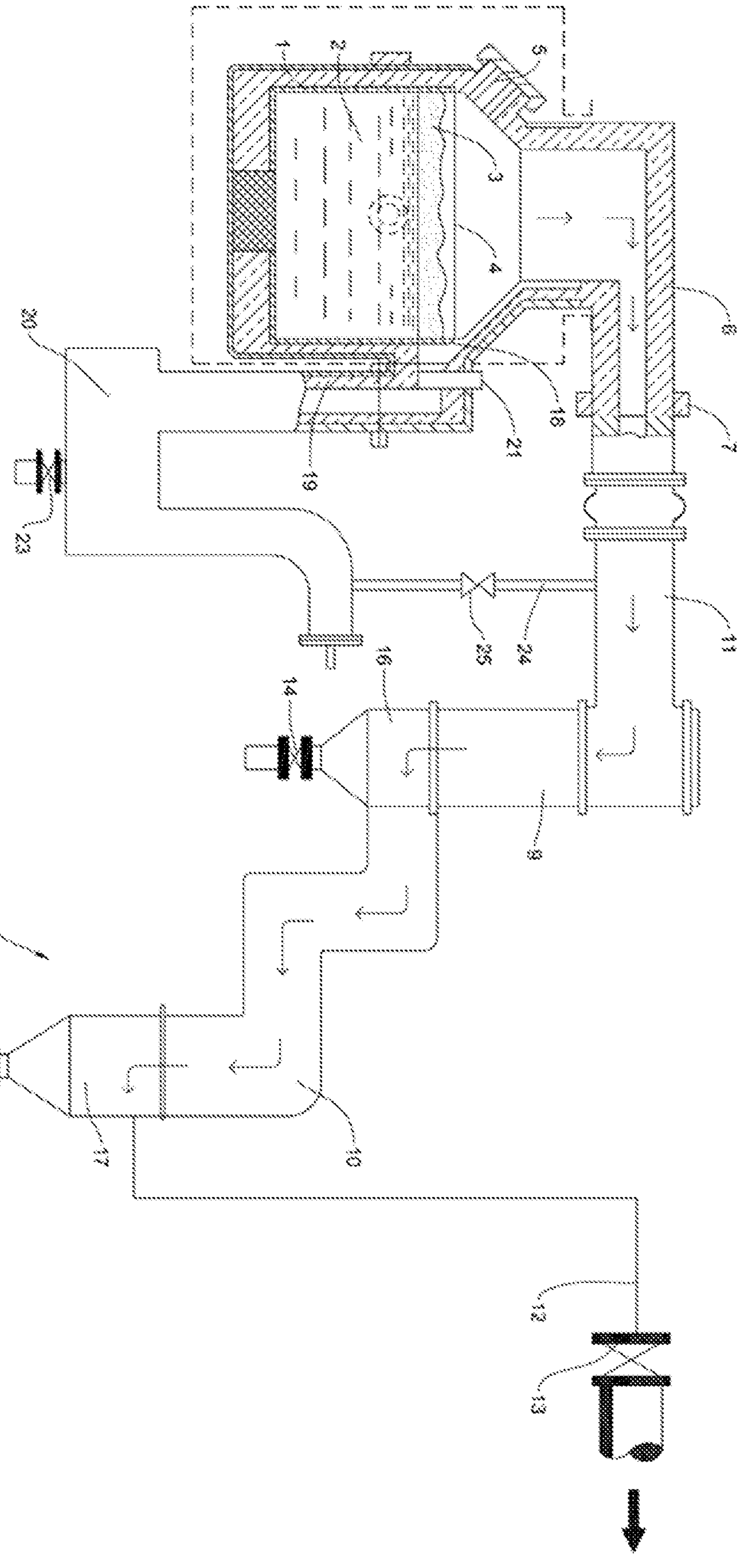


FIG. 2

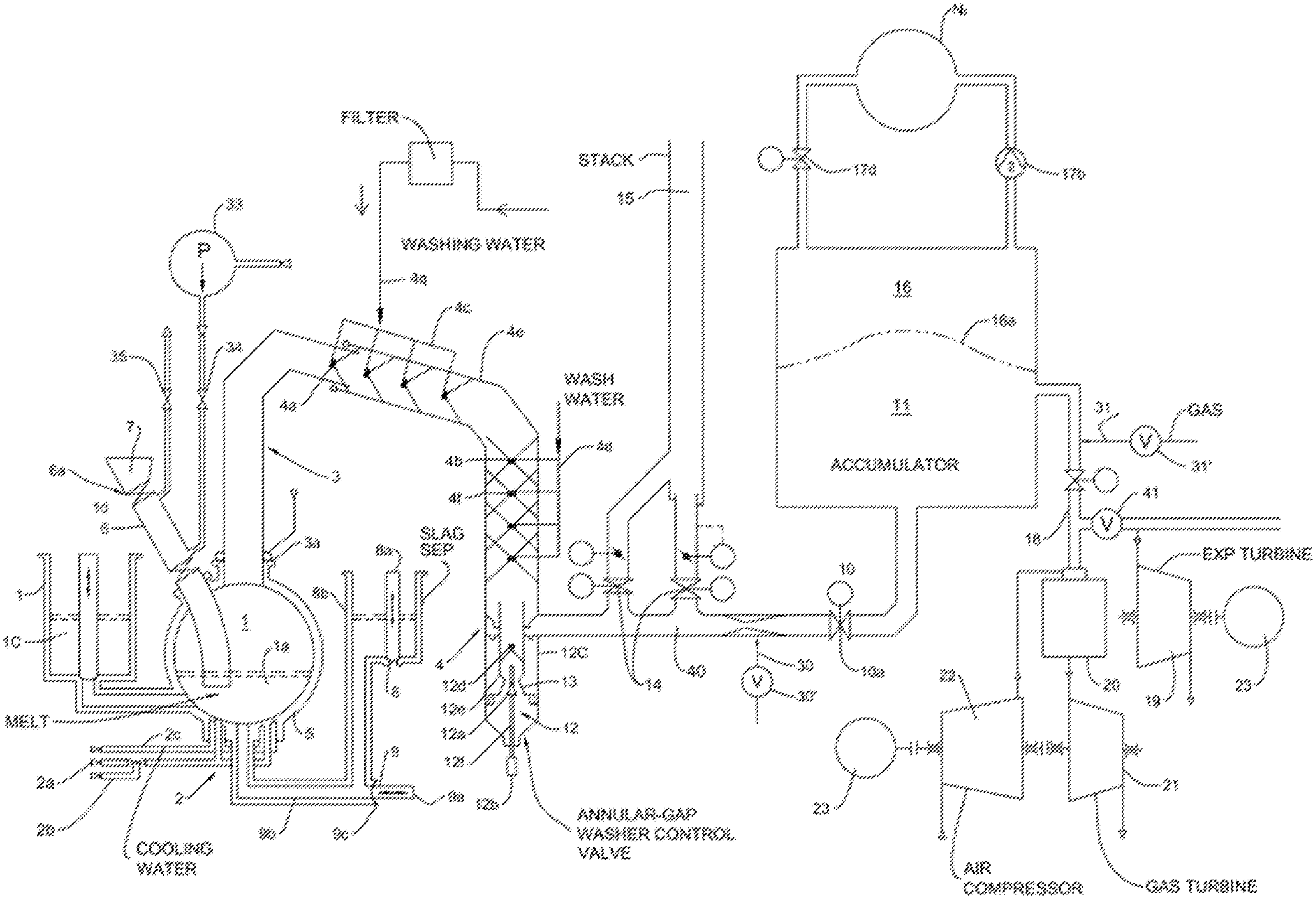

FILTER
33
P
WASHING WATER
4q
4c
4e
35
34
7
6a
1d
6
1
1C
MELT
1
1a
3
3a
9
4a
4s
5
8a
8b
SLAG SEP
8
9
9a
9b
9c
2
2a
2b
2c
COOLING WATER
WASH WATER
4d
4b
4f
4
12d
12e
12a
12f
12b
12C
13
12
ANNULAR-GAP WASHER CONTROL VALVE
STACK
15
14
40
30
V
30'
10
10a
N₂
17a
17b
16
16a
11
ACCUMULATOR
31
V
GAS
31'
41
V
18
EXP TURBINE
20
19
23
22
AIR COMPRESSOR
21
GAS TURBINE
23

FIG 3

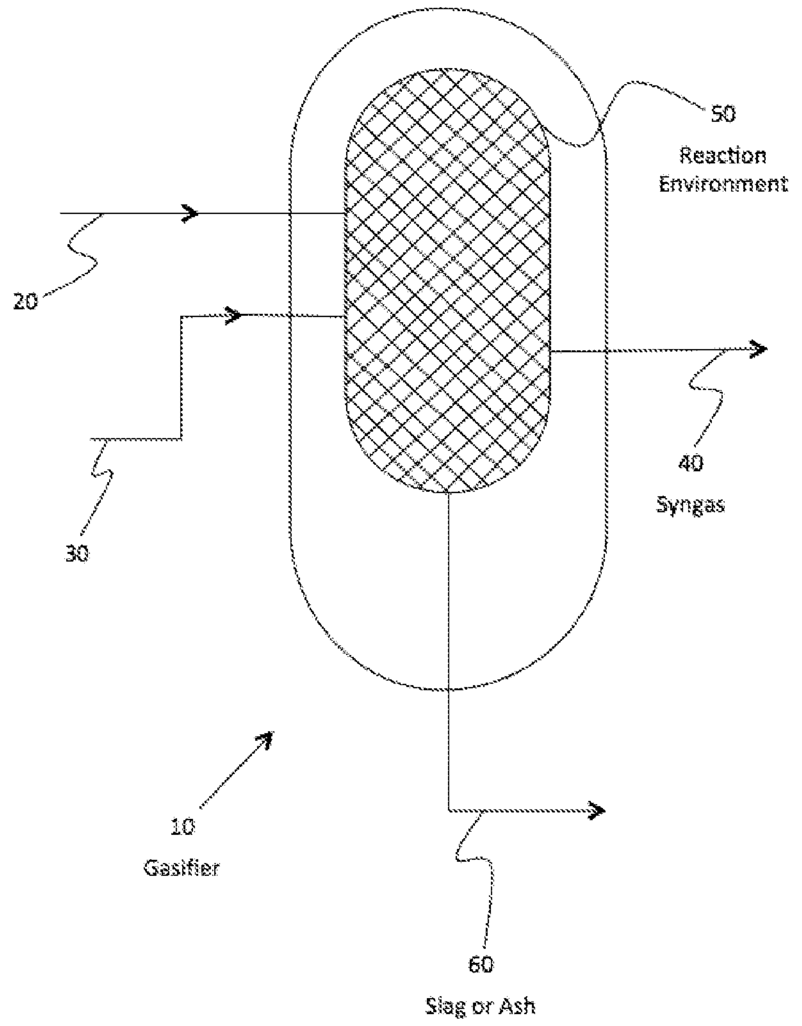

50
Reaction
Environment
20
30
40
Syngas
10
Gasifier
60
Slag or Ash

FIG 4

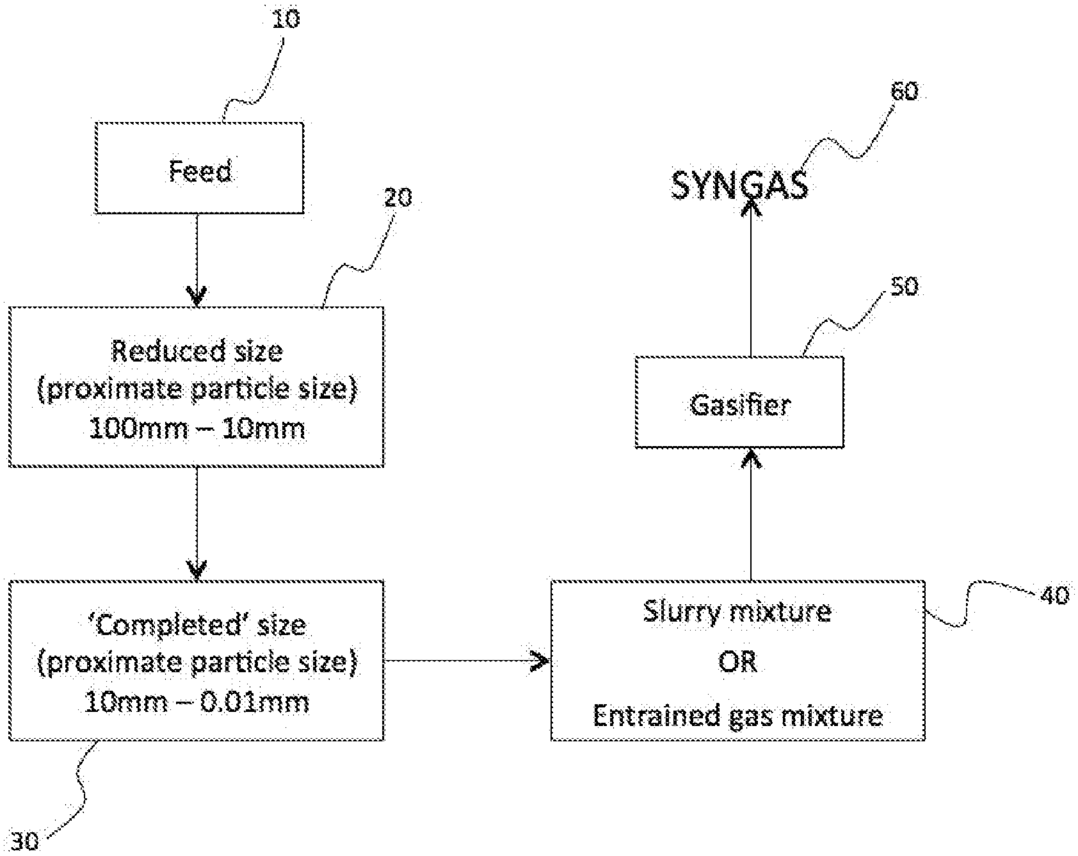

10
Feed
20
Reduced size
(proximate particle size)
100mm – 10mm
'Completed' size
(proximate particle size)
10mm – 0.01mm
30
Slurry mixture
OR
Entrained gas mixture
40
Gasifier
50
SYNGAS
60

FIG. 5

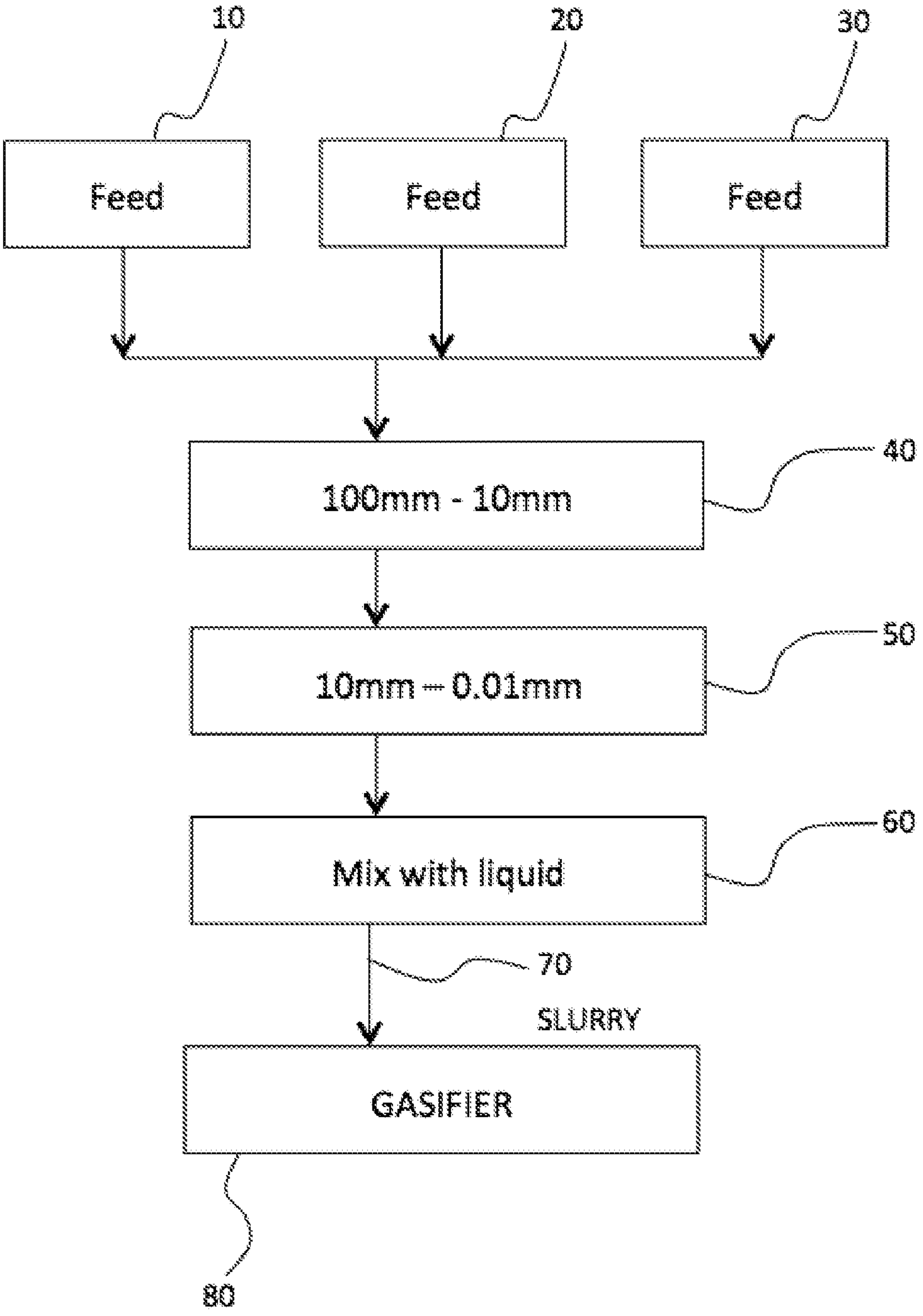
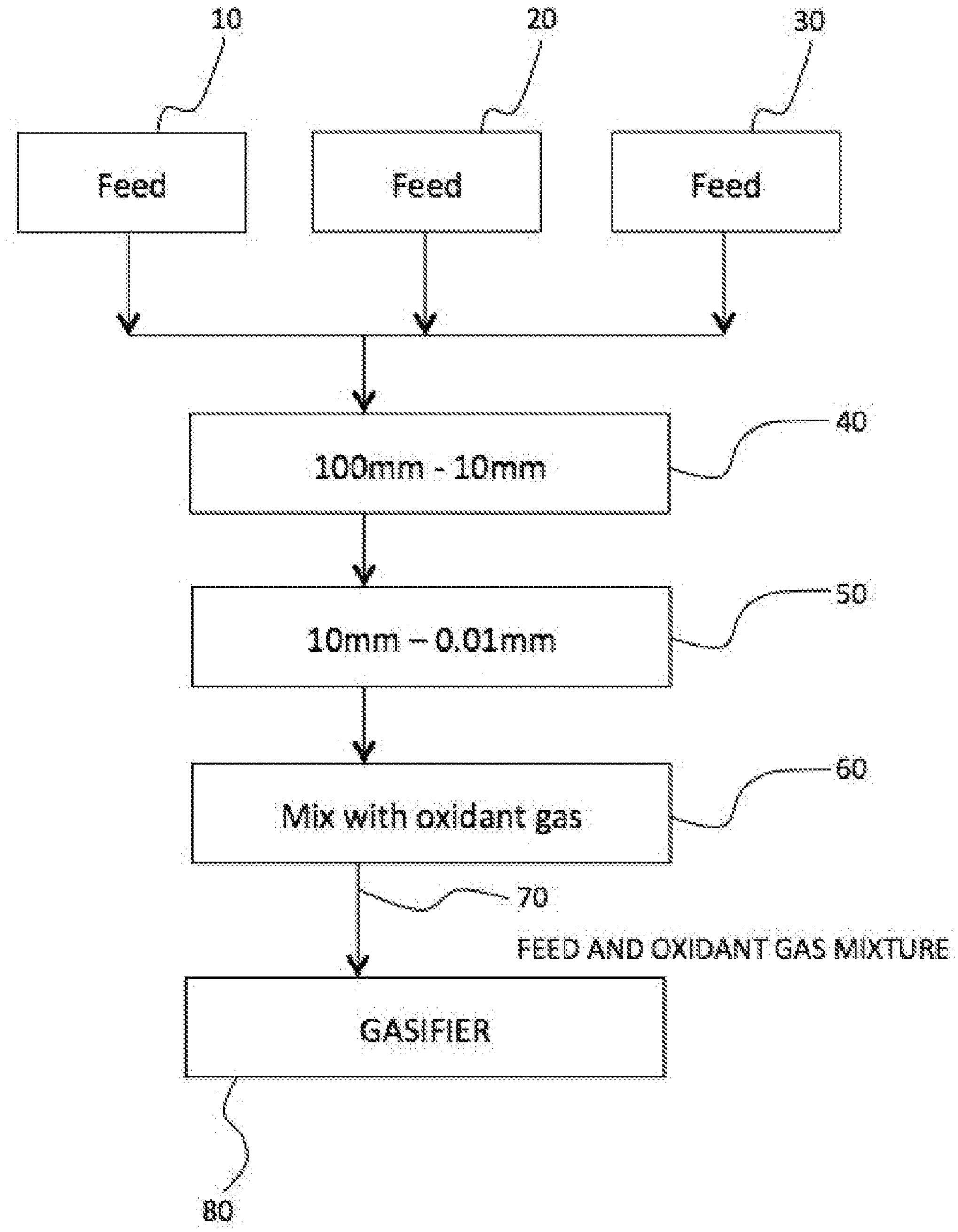

10
20
30
Feed
Feed
Feed
100mm - 10mm
40
10mm – 0.01mm
50
Mix with liquid
60
70
SLURRY
GASIFIER
80

FIG. 6


10
20
30
Feed
Feed
Feed
100mm - 10mm
40
10mm – 0.01mm
50
Mix with oxidant gas
60
70
FEED AND OXIDANT GAS MIXTURE
GASIFIER
80

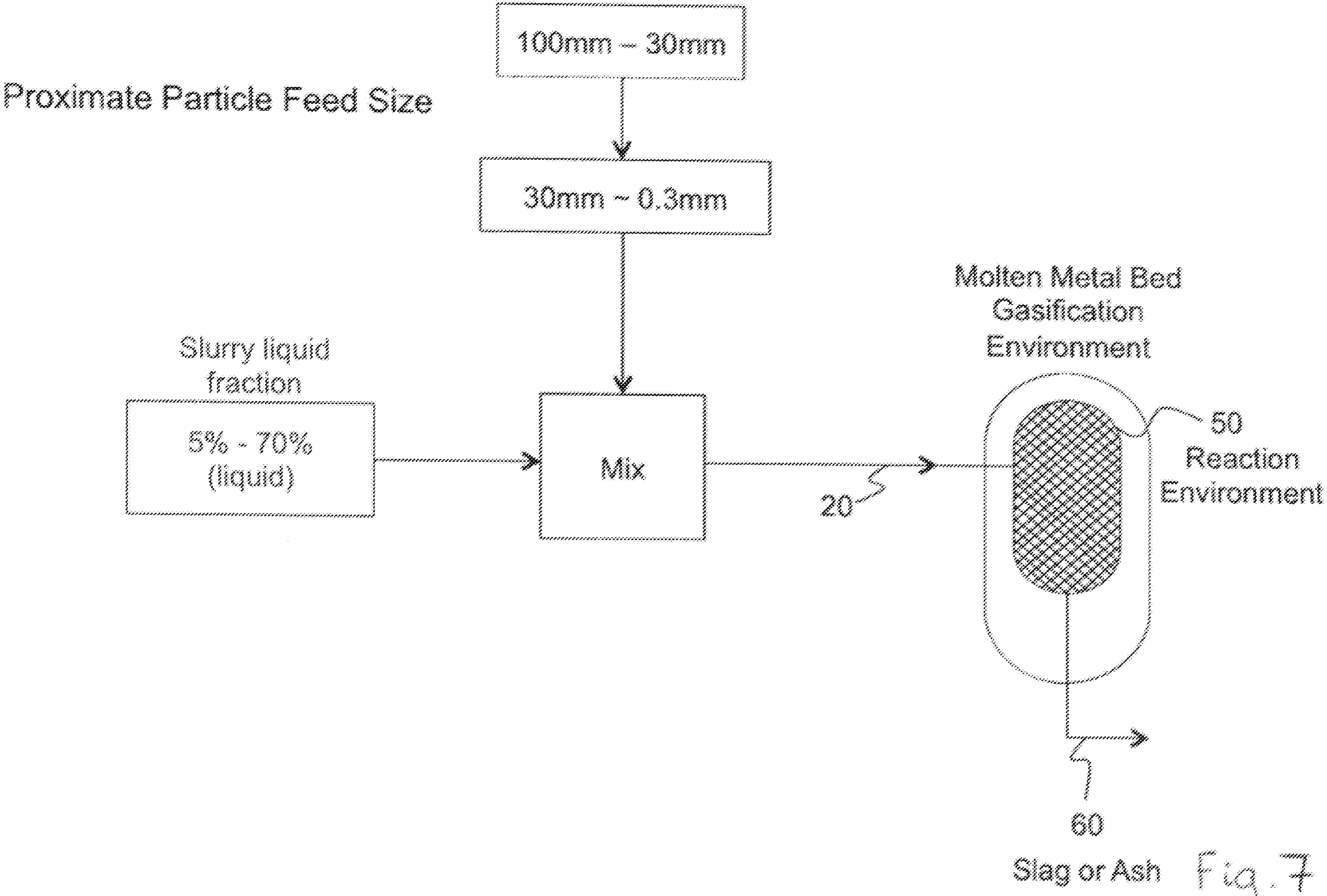

Proximate Particle Feed Size
100mm – 30mm
30mm ~ 0.3mm
Slurry liquid fraction
5% - 70% (liquid)
Mix
20
Molten Metal Bed Gasification Environment
50
Reaction Environment
60
Slag or Ash

Fig. 7

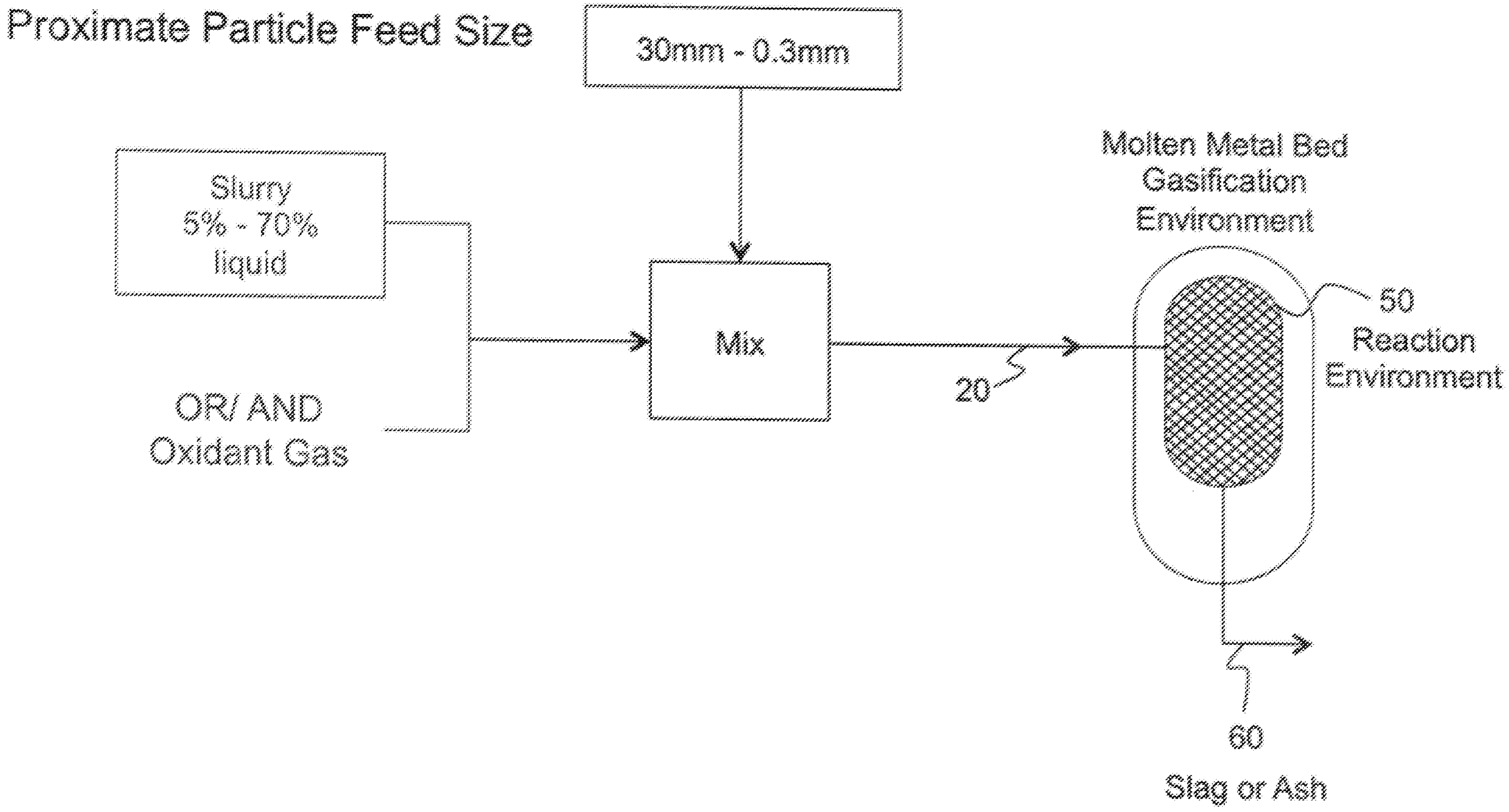

Proximate Particle Feed Size
30mm - 0.3mm
Slurry
5% - 70%
liquid
OR/ AND
Oxidant Gas
Mix
20
Molten Metal Bed
Gasification
Environment
50
Reaction
Environment
60
Slag or Ash

Fig. 8

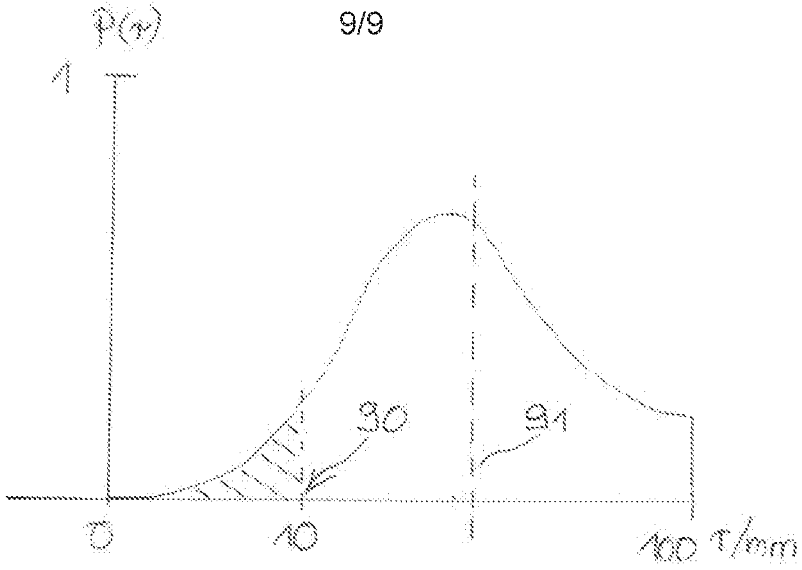


Fig. 9

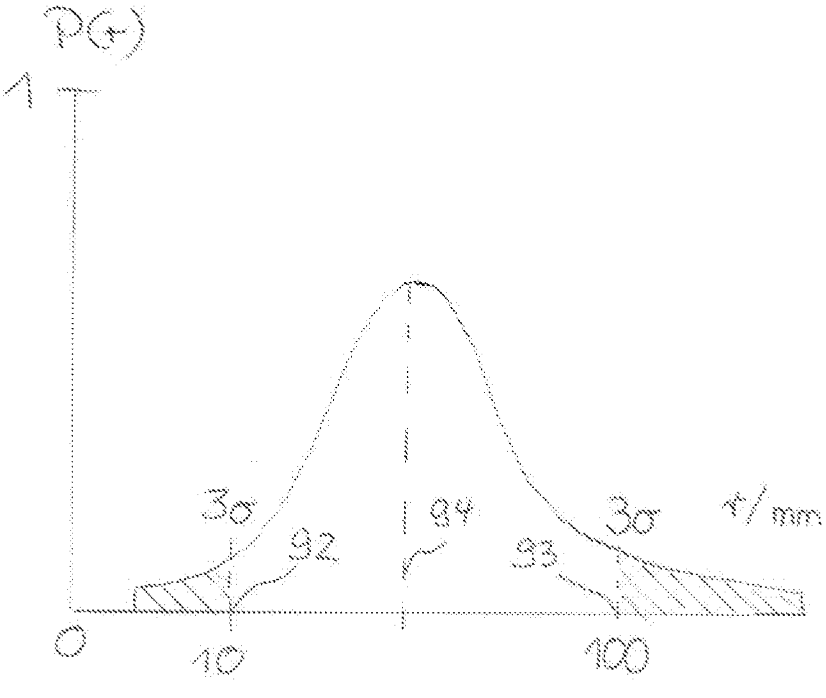


Fig. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2014/058486

A. CLASSIFICATION OF SUBJECT MATTER

C10J 3/57(2006.01)i, C10J 3/20(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10J 3/57; B09B 3/00; B63B 35/44; C07C 1/00; B01J 8/00; C10J 3/20; C02F 1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: synthesis gas, molten metal, gasifier, size reduction, remote site

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2008-057051 A1 (GUEH, HOW KIAP) 15 May 2008 See page 5, line 16 - page 8, line 23, page 10, lines 8-25; claims 1-31; and figures 1-2.	1-27
Y	WO 2007-037768 A1 (GEP YESIL ENERJI URETIM TEKNOLOJILERI LIMITED SIRKETI) 5 April 2007 See page 6, line 15 - page 10, line 1; claim 1; and figure 1.	1-27
A	US 5984985 A (MALONE, DONALD P.) 16 November 1999 See column 3, line 13 - column 5, line 35; claims 1-10; and figure 1.	1-27
A	US 2005-0051500 A1 (PRICE, CHARLES E. et al.) 10 March 2005 See abstract; paragraphs [0029]-[0041]; and figures 1-2.	1-27
A	US 2011-0158858 A1 (ALVES RAMALHO GOMES, MARIO LUIS) 30 June 2011 See paragraphs [0038]-[0039].	1-27

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 20 May 2014 (20.05.2014)	Date of mailing of the international search report **20 May 2014 (20.05.2014)**
Name and mailing address of the ISA/KR International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. +82-42-472-7140	Authorized officer LEE, Dong Wook Telephone No. +82-42-481-8163

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		EP 2176385 A1	21/04/2010
		WO 2008-130260 A1	30/10/2008