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(54) **CYCLONE INTEGRATED TYPE STORAGE DEVICE, INTEGRATED GASIFICATION COMBINED CYCLE, AND METHOD FOR SEPARATING PARTICLES**

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(57) **ABSTRACT**

A cyclone integrated type storage device that helps to reduce equipment costs, which includes: a hollow pressure vessel; a cyclone provided in a vertically upper part of the pressure vessel and configured to swirl a produced gas introduced from outside and containing particles to thereby separate at least some of char from the produced gas, the cyclone including an opening and an exhaust port, the opening permitting discharge of the separated char vertically downward in the pressure vessel, the exhaust port permitting discharge of the produced gas to the outside of the pressure vessel; a particle storage chamber provided in a vertically lower part of the pressure vessel and storing the char discharged through the opening; and an outlet port formed in a bottom of the pressure vessel and permitting discharge of the particles stored in the particle storage chamber to the outside.

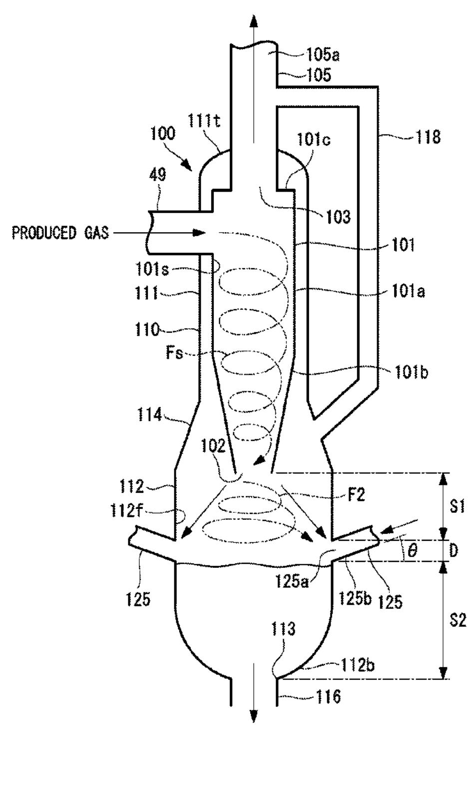

FIG. 1

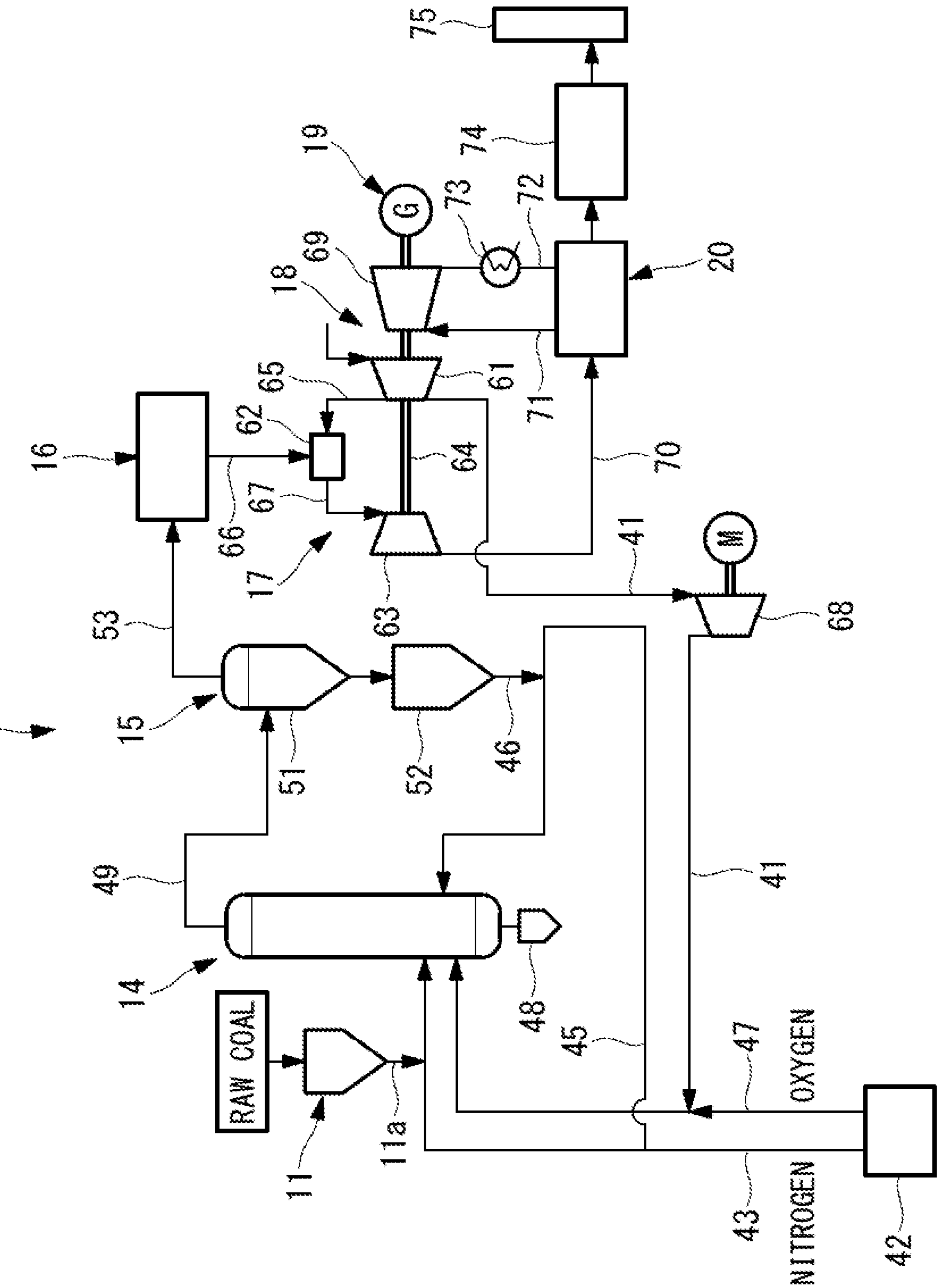
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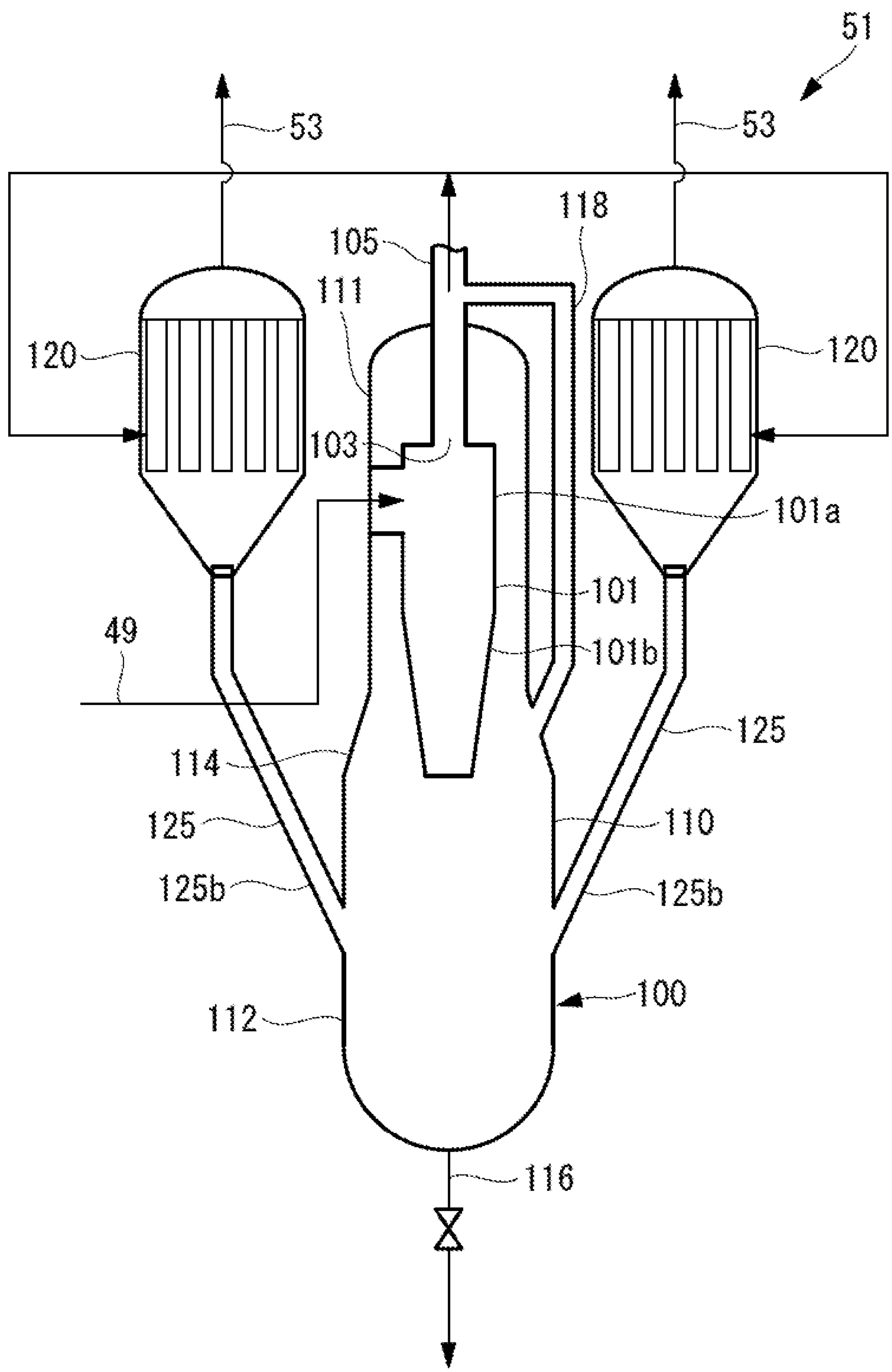
FIG. 2



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101b
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110
125b
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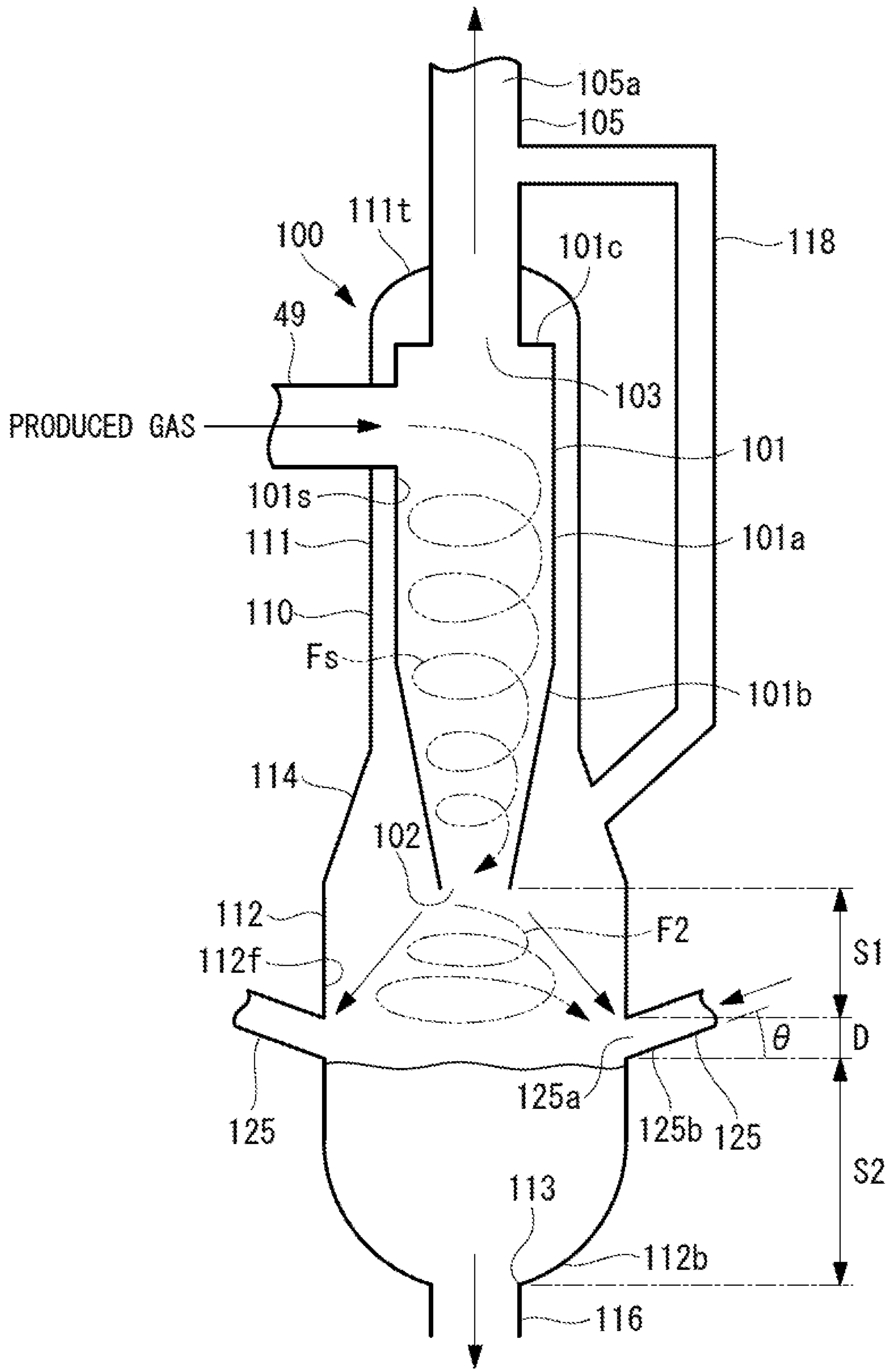
100
112
116

FIG. 3



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CYCLONE INTEGRATED TYPE STORAGE DEVICE, INTEGRATED GASIFICATION COMBINED CYCLE, AND METHOD FOR SEPARATING PARTICLES

TECHNICAL FIELD

[0001] The present invention relates to a cyclone integrated type storage device, an integrated gasification combined cycle, and a method for separating particles.

BACKGROUND ART

[0002] A known example of gasification unit is the carbonaceous fuel gasification apparatus (coal gasification unit) that supplies a carbonaceous feedstock such as coal into a gasifier and partially combusts and gasifies the fuel to produce a combustible gas.

[0003] An integrated coal gasification combined cycle (hereinafter referred to as “IGCC”) system typically consists of a coal feeder, a coal gasifier, a char recovery unit (e.g., a cyclone and a porous filter), a gas purification unit, a gas turbine, a steam turbine, a generator, a heat recovery steam generator, and a gasification agent feeder.

[0004] In such an integrated coal gasification combined cycle system, coal (pulverized coal) is supplied from the coal feeder to the coal gasifier, and a gasification agent (e.g., air, oxygen-rich air, oxygen, and steam) is also supplied from the gasification agent feeder to the coal gasifier.

[0005] In the coal gasifier, the coal is partially oxidized and gasified by the gasification agent, producing a combustible gas (coal gas). Since the produced combustible gas contains particles (char) that are unreacted solids of the coal, the char recovery unit recovers the char and thus removes dust from the combustible gas. The combustible gas from which dust has been removed then undergoes purification by the gas purification unit, whereby impurities such as sulfur compounds and nitrogen compounds are removed. This turns the combustible gas into fuel gas, which is supplied to the gas turbine.

[0006] Patent Literatures 1 and 2 each disclose a char recovery unit including a cyclone (a centrifugal remover), a char bin (container), and a char supply hopper.

[0007] The cyclone recovers char from a combustible gas. The bin temporarily stores the char recovered by the cyclone. The char supply hopper supplies the char supplied from the bin to a char return line. The char supplied to the char return line is returned to the coal gasifier and recycled.

CITATION LIST

Patent Literature

[PTL 1]

[0008] The Publication of Japanese Patent No. 5518161

[PTL 2]

[0009] The Publication of Japanese Patent No. 5529678

SUMMARY OF INVENTION

Technical Problem

[0010] In the above configuration, the high-temperature and high-pressure combustible gas (produced gas) produced in the coal gasifier is sent into the cyclone. This causes a temperature difference between the cyclone and the bin, resulting in a difference in thermal elongation between the cyclone and the bin. To absorb this difference in thermal elongation, a thermal expansion absorber such as a bellows expansion member is required for a connection pipe that supplies the char from the cyclone to the bin. This leads to a complicated equipment configuration, which may increase equipment costs.

[0011] The present invention has been made in view of the above circumstances, and aims to provide a cyclone integrated type storage device, an integrated gasification combined cycle, and a method for separating particles each of which helps simplify the equipment configuration and reduces equipment costs.

Solution to Problem

[0012] According to a first aspect of the present invention, there is provided a cyclone integrated type storage device including: a hollow pressure vessel; a cyclone provided in a vertically upper part of the pressure vessel, the cyclone being configured to swirl gas introduced from outside and containing particles to thereby separate at least some of the particles from the gas, the cyclone including an opening and an exhaust port, the opening permitting discharge of the separated particles vertically downward in the pressure vessel, the exhaust port permitting discharge of the gas to the outside of the pressure vessel; a particle storage chamber provided in a vertically lower part of the pressure vessel, the particle storage chamber storing the particles discharged through the opening; and a outlet port formed in a bottom of the pressure vessel, the outlet port permitting discharge of the particles stored in the particle storage chamber to the outside.

[0013] In this configuration, the cyclone to separate particles from the introduced gas (produced gas) is contained in the vertically upper part of the pressure vessel in which the particle storage chamber is provided. This eliminates the need for separately providing the cyclone and a container (bin) for storing the particles. This in turn eliminates the need for a pipe to connect the cyclone and the container and an expansion member, and thus simplifies the equipment configuration, helping to reduce equipment costs.

[0014] Since the cyclone is contained in the pressure vessel, the cyclone itself does not need to have a pressure resistant structure. In this respect too, equipment costs can be reduced.

[0015] In the above first aspect, the cyclone integrated type storage device preferably further includes a equalization pipe configured to communicate between an inside of the pressure vessel and an inside of a flow path of the gas discharged from the exhaust port.

[0016] In this configuration, when the particles separated by the cyclone fall down into the particle storage chamber located vertically below the cyclone, the gas present in the pressure vessel flows, by the amount equal to the volume of the fallen particles, through the equalization pipe into the flow path of the gas to be discharged through the exhaust port. This allows evening out the pressure between the inside of the pressure vessel and the inside of the flow path of the gas to be discharged through the exhaust port.

[0017] In the above first aspect, the equalization pipe preferably communicates with the inside of the pressure vessel at a position vertically above the opening.

[0018] This configuration prevents the particles separated by the cyclone from flying within the pressure vessel and rediffusing into the equalization pipe.

[0019] In the above first aspect, the particle storage chamber preferably further includes: a particle diffusion space in which a flow of the particles discharged through the opening gradually diffuses radially outward in the particle storage chamber, a lower boundary of the particle diffusion space coinciding with a position at which the diffusing particles hit an inner surface of the particle storage chamber; and a particle accumulation space formed vertically below the particle diffusion space, the particle accumulation space permitting accumulation of the particles on the bottom of the pressure vessel.

[0020] This configuration provides a space for accumulating the particles that have been discharged from the cyclone on the swirling flow and hit the inner surface of the particle storage chamber to fall downward. This prevents the particles from flying or rediffusing, and allows accumulating the particles in the particle accumulation space.

[0021] In the above first aspect, the cyclone integrated type storage device preferably further includes a feeding pipe that is connected to a filter that captures fine particles unseparated from the gas in the cyclone and discharged through the exhaust port along with the gas and that is configured to send the fine particles captured by the filter into the particle storage chamber, and the feeding pipe preferably communicates with the particle storage chamber at a position vertically below the particle diffusion space and vertically above the particle accumulation space.

[0022] In this configuration, the feeding pipe communicates with the particle storage chamber at a position vertically below the particle diffusion space. This causes fine particles sent through the feeding pipe into the particle storage chamber to be moved vertically downward by the flow of gas within the particle storage chamber, preventing the fine particles from flying vertically upward. Further, the feeding pipe communicates with the particle storage chamber at the position vertically above the particle accumulation space. Thus, the flow of fine particles sent through the feeding pipe prevents the particles accumulated in the particle accumulation space from flying upward.

[0023] In the above first aspect, a distance between a lower end of the particle diffusion space and an upper end of the particle accumulation space is preferably equal to an opening diameter of a connection port of the feeding pipe facing the particle storage chamber.

[0024] This configuration appropriately minimizes the size of the boundary between the lower end of the particle diffusion space and the upper end of the particle accumulation space. This prevents an increase in the size of the pressure vessel.

[0025] In the above first aspect, an end of the feeding pipe on a connection port side thereof facing the particle storage chamber is further preferably inclined obliquely downward at 20° or more relative to a horizontal direction.

[0026] In this configuration, the large inclination of the feeding pipe prevents the fine particles sent through the feeding pipe into the particle storage chamber from flying into the particle diffusion space and rediffusing into the equalization pipe.

[0027] According to a second aspect of the present invention, there is provided an integrated gasification combined cycle including the cyclone integrated type storage device of the above first aspect.

[0028] According to a third aspect of the present invention, there is provided a method for separating particles in the aforementioned cyclone integrated type storage device, the method including: introducing gas containing the particles from outside into the cyclone provided in the upper part of the pressure vessel, and swirling the gas to thereby separate the particles from the gas; discharging the particles separated within the cyclone downward through the opening formed at the lower end of the cyclone; storing the particles discharged downward through the opening in the particle storage chamber provided in the lower part of the pressure vessel; and discharging the particles stored in the particle storage chamber to the outside through the outlet port formed in the bottom of the pressure vessel.

Advantageous Effects of Invention

[0029] The present invention simplifies the equipment configuration, helping to reduce equipment costs.

BRIEF DESCRIPTION OF DRAWINGS

[0030] FIG. **1** illustrates a schematic configuration of an integrated coal gasification combined cycle system including a cyclone integrated type storage device according to an embodiment of the present invention.

[0031] FIG. **2** illustrates a configuration of a dust collector including the cyclone integrated type storage device according to the embodiment of the present invention.

[0032] FIG. **3** is a vertical cross-sectional view of the cyclone integrated type storage device according to the embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0033] Embodiments of the present invention will be described below with reference to the drawings.

[0034] First of all, an explanation will be given of an integrated coal gasification combined cycle system, which is one embodiment of the integrated gasification combined cycle of the present invention.

[0035] As shown in FIG. **1**, the integrated coal gasification combined cycle (IGCC) system **10** employs an air combustion method whereby the integrated coal gasification combined cycle system **10** uses air as a main oxidation agent and produces a combustible gas (produced gas) from fuel in a gasification unit **14**. The integrated coal gasification combined cycle system (the integrated gasification combined cycle) **10** then purifies the produced gas produced in the gasification unit **14** into fuel gas in a gas purification unit **16**, and supplies the fuel gas to a gas turbine **17** for power generation. In other words, the integrated coal gasification combined cycle system **10** of the present embodiment is an air combustion type (air-blown) power generating system. Examples of the fuel supplied to the gasification unit **14** include carbonaceous feedstocks such as coal.

[0036] The integrated coal gasification combined cycle system **10** includes a coal feeder **11**, the gasification unit **14**, a char recovery unit **15**, the gas purification unit **16**, the gas turbine **17**, a steam turbine **18**, a generator **19**, and a heat recovery steam generator (HRSG) **20**.

[0037] The coal feeder **11** is supplied with raw coal, which is a carbonaceous feedstock, and pulverizes the coal by a coal mill and the like (not shown in the figure) to produce pulverized coal consisting of fine particles. The pulverized coal produced by the coal feeder **11** is pressurized at an outlet of a coal feeding line **11***a* by nitrogen gas supplied from an air separation unit **42** (described later) as conveyance inert gas, and is then supplied to the gasification unit **14**. The inert gas is a gas that contains about 5 or less volume percent of oxygen, and representative examples include nitrogen gas, carbon dioxide gas and argon gas. However, the volume percent of oxygen is not necessarily limited to 5 or less.

[0038] The gasification unit **14** is supplied with the pulverized coal produced by the coal feeder **11**, and also supplied with char (unreacted coal and ash) recovered by the char recovery unit **15** and returned to the gasification unit **14** for their reuse.

[0039] Connected to the gasification unit **14** is a compressed air supply line **41** extending from the gas turbine **17** (a compressor **61**). This allows a part of compressed air compressed by the gas turbine **17** to be boosted to a predetermined pressure by a booster **68** before being supplied to the gasification unit **14**. The air separation unit **42** separates nitrogen and oxygen from the atmospheric air. The air separation unit **42** and the gasification unit **14** are connected with a first nitrogen supply line **43**. Connected to the first nitrogen supply line **43** is the coal feeding line **11***a* extending from the coal feeder **11**. Also connected to the gasification unit **14** is a second nitrogen supply line **45** branching off from the first nitrogen supply line **43**. Connected to the second nitrogen supply line **45** is a char return line **46** extending from the char recovery unit **15**. The air separation unit **42** and the compressed air supply line **41** are connected with an oxygen supply line **47**. Nitrogen separated by the air separation unit **42** circulates through the first nitrogen supply line **43** and the second nitrogen supply line **45** to be used as a conveyance gas for coal and char. Oxygen separated by the air separation unit **42** circulates through the oxygen supply line **47** and the compressed air supply line **41** to be used as an oxidation agent in the gasification unit **14**.

[0040] The gasification unit **14** includes, for example, a two-stage entrained bed gasifier. The gasification unit **14** partially combusts the internally supplied coal (pulverized coal) and char by the oxidation agent (air and oxygen) to gasify them into a produced gas (gas). The gasification unit **14** is provided with a foreign object remover **48** that removes foreign objects (slag) mixed into the pulverized coal. Connected to the gasification unit **14** is a gas generation line **49** to supply the produced gas to the char recovery unit **15**. This allows the gasification unit **14** to discharge the produced gas containing the char. The gas generation line **49** may be provided with a syngas cooler (gas cooler) to cool the produced gas to a predetermined temperature before supplying it to the char recovery unit **15**.

[0041] The char recovery unit **15** includes a dust collector **51** and a char supply hopper **52**. The dust collector **51** separates the char contained in the produced gas produced by the gasification unit **14**. The produced gas from which the char has been separated is sent through a gas discharge line **53** to the gas purification unit **16**. The char supply hopper **52** stores the char separated from the produced gas by the dust collector **51**. The char return line **46** extending from the char supply hopper **52** is connected to the second nitrogen supply line **45**.

[0042] The gas purification unit **16** removes impurities, such as sulfur compounds and nitrogen compounds, from the produced gas from which the char has been separated by the char recovery unit **15**, and thereby purifies the gas. The gas purification unit **16** purifies the produced gas into fuel gas and supplies the fuel gas to the gas turbine **17**. Since the produced gas from which the char has been separated still contains sulfur components (e.g., H_2S), the gas purification unit **16** removes and recovers the sulfur components by amine absorption liquid and the like for their effective use.

[0043] The gas turbine **17** includes the compressor **61**, a combustor **62**, and a turbine **63**. The compressor **61** and the turbine **63** are coupled with a rotary shaft **64**. Connected to the combustor **62** is a compressed air supply line **65** extending from the compressor **61**, a fuel gas supply line **66** extending from the gas purification unit **16**, and a combustion gas supply line **67** extending to the turbine **63**. The gas turbine **17** is provided with the compressed air supply line **41** extending from the compressor **61** to the gasification unit **14**, and the booster **68** is provided in the middle of the compressed air supply line **41**. Thus, the combustor **62** mixes a part of the compressed air supplied from the compressor **61** and at least a part of the fuel gas supplied from the gas purification unit **16** and combusts them to generate a combustion gas, and supplies the generated combustion gas to the turbine **63**. The turbine **63** rotates the rotary shaft **64** by the supplied combustion gas and thereby drives the generator **19**.

[0044] A steam turbine **18** includes a turbine **69** coupled to the rotary shaft **64** of the gas turbine **17**. The generator **19** is coupled to a base end of the rotary shaft **64**. The heat recovery steam generator **20** is connected to a flue gas line **70** extending from the gas turbine **17** (the turbine **63**), and exchanges heat between the water supplied to the heat recovery steam generator **20** and the flue gas discharged from the turbine **63** to thereby generate steam. The heat recovery steam generator **20** is provided with a steam supply line **71** connected to the turbine **69** of the steam turbine **18** and also provided with a steam recovery line **72**, which is provided with a condenser **73**. The steam generated by the heat recovery steam generator **20** may include steam generated through heat exchange with the produced gas in the syngas cooler of the gasification unit **14**. Thus, in the steam turbine **18**, the turbine **69** is rotated by the steam supplied from the heat recovery steam generator **20** so as to rotate the rotary shaft **64**, whereby the generator **19** is driven.

[0045] A gas cleaning unit **74** is provided between an outlet of the heat recovery steam generator **20** and a stack **75**.

[0046] An explanation will be given of operations of the integrated coal gasification combined cycle **10** of the present embodiment.

[0047] In the integrated coal gasification combined cycle **10** of the present embodiment, the coal feeder **11** pulverizes supplied raw coal (coal) by its coal mill (not shown in the figure) into pulverized coal consisting of fine particles. The pulverized coal produced by the coal feeder **11** is made flow through the first nitrogen supply line **43** by nitrogen supplied from the air separation unit **42**, and thus supplied to the gasification unit **14**. The char recovered by the char recovery unit **15** (described later) is made flow through the second nitrogen supply line **45** by nitrogen supplied from the air separation unit **42**, and thus supplied to the gasification unit **14**. The compressed air extracted from the gas turbine **17** (described later) is boosted by the booster **68** before being supplied to the gasification unit **14** via the compressed air supply line **41** together with oxygen supplied from the air separation unit **42**.

[0048] The gasification unit **14** combusts the supplied pulverized coal and char by the compressed air (oxygen) to gasify the pulverized coal and char, thus producing the produced gas. The produced gas is discharged from the gasification unit **14** through the gas generation line **49** to the char recovery unit **15**.

[0049] In the char recovery unit **15**, the produced gas is first supplied to the dust collector **51**, where fine char contained in the produced gas is separated from the produced gas. The produced gas from which the char has been removed is sent through the gas discharge line **53** to the gas purification unit **16**. Meanwhile, the fine char separated from the produced gas is accumulated on the char supply hopper **52**, and returned through the char return line **46** to the gasification unit **14** to be recycled.

[0050] The produced gas from which the char has been separated by the char recovery unit **15** undergoes gas purification by the gas purification unit **16**, whereby impurities such as sulfur compounds and nitrogen compounds are removed from the produced gas. This produces the fuel gas. The compressor **61** produces the compressed air and supplies it to the combustor **62**. The combustor **62** mixes the compressed air supplied from the compressor **61** and the fuel gas supplied from the gas purification unit **16** and combusts them to produce the combustion gas. The turbine **63** is rotated by this combustion gas, which in turn drives the compressor **61** and the generator **19** via the rotary shaft **64**. Thus, the gas turbine **17** can generate power.

[0051] The heat recovery steam generator **20** exchanges heat between the flue gas discharged from the turbine **63** of the gas turbine **17** and the water supplied to the heat recovery steam generator **20** to produce steam, and supplies the produced steam to the steam turbine **18**. In the steam turbine **18**, the turbine **69** is rotated by the steam supplied from the heat recovery steam generator **20**, which in turn drives the generator **19** via the rotary shaft **64**, generating power.

[0052] It is not essential that the gas turbine **17** and the steam turbine **18** are coaxially arranged to drive one generator **19**; the gas turbine **17** and the steam turbine **18** may be on different axes to drive multiple generators.

[0053] Thereafter, toxic substances in the flue gas discharged from the heat recovery steam generator **20** are removed in the gas cleaning unit **74**, and the cleaned flue gas is discharged through the stack **75** to the atmosphere.

[0054] A detailed explanation will be given of the dust collector **51** provided to the aforementioned char recovery unit **15**.

[0055] As shown in FIG. **2**, the dust collector **51** includes a cyclone integrated type storage device **100** as a primary dust collector, and a porous filter (filter) **120** as a secondary dust collector.

[0056] As shown in FIGS. **2** and **3**, the cyclone integrated type storage device **100** includes a pressure vessel **110** and a cyclone **101**.

[0057] The pressure vessel **110** is hollow and resistant against pressure of the high-temperature and high-pressure produced gas sent from the gasification unit **14** through the gas generation line **49**. The pressure vessel **110** includes a cyclone chamber **111** formed in an upper part of the pressure vessel **110**, and a particle storage chamber **112** formed in a lower part of the pressure vessel **110**.

[0058] The cyclone chamber **111** has a cylindrical shape continuous in a vertical direction, and contains the cyclone **101** inside thereof. The cyclone chamber **111** includes a top lilt having, for example, a dome shape whose inner diameter gradually decreases vertically upward.

[0059] The particle storage chamber **112** has a cylindrical shape whose inner diameter is larger than that of the cyclone chamber **111**. Thus, the particle storage chamber **112** has a larger horizontal cross-sectional area than that of the cyclone chamber **111**, ensuring a storage capacity for the char (particles) while reducing the vertical size of the particle storage chamber **112**. This in turns prevents the pressure vessel **110** from increasing its vertical size.

[0060] The particle storage chamber **112** is formed below a lower end of the cyclone chamber **111**. The particle storage chamber **112** is continuous from the cyclone chamber **111** via a widened part **114** whose inner diameter gradually increases downward.

[0061] The particle storage chamber **112** includes a bottom **112*b*** having, for example, a mortar shape whose inner diameter gradually decreases downward. An inner surface of the bottom **112*b*** of the particle storage chamber **112** is inclined at an angle equal to or larger than an angle of repose of the char accumulated in the particle storage chamber **112**. This facilitates discharge of the char accumulated in the particle storage chamber **112** toward a outlet port **113**.

[0062] The outlet port **113** that opens downward is formed in the bottom **112*b*** of the particle storage chamber **112**. Connected to the outlet port **113** is a char supply pipe **116** that communicates with the char supply hopper **52**. Opening and closing a valve (not shown in the figure) provided on the way of the char supply pipe **116** enables to discharge the char.

[0063] The cyclone **101** contained in the cyclone chamber **111** includes a cylindrical part **101*a*** continuous in the vertical direction and a tapered part **101*b*** whose inner diameter gradually decreases downward from a lower end of the cylindrical part **101*a***. The cylindrical part **101*a*** and the tapered part **101*b*** are integrated in a single body. An upper end of the cylindrical part **101*a*** is closed by a disc-like plate **101*c*** so as to connect to an exhaust pipe **105**. A lower end of the tapered part **101*b*** is provided with an opening **102** through which the char is discharged downward in the pressure vessel **110**.

[0064] The plate **101*c*** at the upper end of the cyclone **101** is provided with an exhaust port **103**. Connected to the exhaust port **103** is the exhaust pipe **105** running vertically upward through the top lilt of the cyclone chamber **111** of the pressure vessel **110**. This forms a flow path through which the produced gas from which the char has been removed by the cyclone **101** (described later) is discharged.

[0065] Connected to a surrounding wall **101*s*** of the cylindrical part **101*a*** of the cyclone **101** is the gas generation line **49** through which the produced gas is sent from the gasification unit **14**. The gas generation line **49** is connected to the surrounding wall **101*s*** of the cyclone **101** in a tangential direction in plan view. This causes the produced gas sent through the gas generation line **49** to swirl in a circumferential direction within the cyclone **101**.

[0066] When the produced gas is sent from the gasification unit **14** through the gas generation line **49** to this cyclone **101**, at least some of the char (in the present embodiment, most of the char) contained in the produced gas, in particular those of coarse particles, are thrown outward within the cyclone **101** by the centrifugal force of a swirling flow Fs generated inside the cyclone **101**. While swirling on the swirling flow Fs, the outwardly thrown char falls down in the gravitational direction by their own weight. Eventually, the char is discharged downward from the cyclone **101** through the opening **102**. In this way, the cyclone **101** centrifugally separates at least some of the char from the produced gas. The produced gas, from which most of the char has been separated with some fine particles left unseparated, is discharged through the exhaust port **103** into the exhaust pipe **105** located above, and sent to the porous filter **120** as the secondary dust collector.

[0067] The char discharged through the opening **102** of the cyclone **101** falls down into the particle storage chamber **112** by their own weight. At this time, a part of a flow F**2** of the char discharged through the opening **102** together with the residual produced gas gradually increases its turning radius by the centrifugal force as it goes downward while swirling by the inertial force of the swirling flow Fs inside the cyclone **101**. Eventually, a part of this flow F**2** falls down in the particle storage chamber **112** by gravity, and another part of the flow F**2** hits an inner surface **112***f* of the particle storage chamber **112**. The char falls downward in the gravitational direction and accumulate on the bottom **112***b* of the particle storage chamber **112** of the pressure vessel **110**.

[0068] Thus, a particle diffusion space S**1** is defined in an upper part of the particle storage chamber **112** where the flow F**2** of the char discharged through the opening **102** falls down while gradually diffusing radially outward and a part of the flow F**2** hits the inner surface of the particle storage chamber **112**. Defined below the particle diffusion space S**1** in the particle storage chamber **112** is a particle accumulation space S**2** where the char accumulates on the bottom of the pressure vessel **110**.

[0069] In other words, the particle diffusion space S**1** is a space that allows the flow F**2** of the char discharged through the opening **102** to diffuse gradually radially outward and that is vertically above the lowest position at which the particles hit the inner surface of the particle storage chamber **112**. The particle accumulation space S**2** is a space that is vertically below the lowest position at which the particles of the flow F**2** of the char discharged through the opening **102** hit the inner surface of the particle storage chamber **112** and also vertically below a connection port **125***a*.

[0070] The char accumulated in the particle accumulation space S**2** of the particle storage chamber **112** of the pressure vessel **110** is supplied from the outlet port **113** through the char supply pipe **116** to the char supply hopper **52** located vertically below. The char supply hopper **52** temporarily stores the char supplied from the cyclone integrated type storage device **100**, and supplies the char through the char return line **46** to the gasification unit **14**.

[0071] Multiple char supply hoppers **52** may be connected to one cyclone integrated type storage device **100**. In this case, multiple outlet ports **113** are formed in the bottom of the pressure vessel **110**, and char supply pipes **116** are connected to the respective discharge ports **113**.

[0072] The cyclone integrated type storage device **100** further includes a equalization pipe **118** that communicates with the inside of the pressure vessel **110** and the inside of the flow path **105***a* of the produced gas in the exhaust pipe **105** connected to the exhaust port **103** of the cyclone **101**. When the char separated from the produced gas by the cyclone **101** falls down into the particle storage chamber **112**, the produced gas present in the particle storage chamber **112** is pushed out into the equalization pipe **118** by the amount equal to the volume of the fallen char. The produced gas having flowed into the equalization pipe **118** is sent into the flow path **105***a* of the exhaust pipe **105**. This prevents an increase in pressure inside the particle storage chamber **112**, evening out the pressure between the inside of the particle storage chamber **112** and the inside of the exhaust pipe **105**.

[0073] The equalization pipe **118** communicates with the pressure vessel **110** at a position vertically above the opening **102** at the lower end of the cyclone **101**. This prevents the fallen char separated by the cyclone **101** from flying and directly flowing into the equalization pipe **118** together with the produced gas pushed out from the particle storage chamber **112** and rediffusing into the flow path **105***a* downstream of the cyclone **101**.

[0074] As shown in FIG. **2**, the produced gas discharged from the exhaust port **103** of the cyclone **101** is sent to the porous filter **120** through the exhaust pipe **105**. The porous filter **120** captures the char (fine particles) unseparated by the cyclone **101** and remaining in the produced gas.

[0075] The produced gas from which the char (fine particles) has been separated by the porous filter **120** is sent through the gas discharge line **53** to the gas purification unit **16**.

[0076] Meanwhile, the fine particles captured by the porous filter **120** are sent through a feeding pipe **125** to the particle storage chamber **112** of the cyclone integrated type storage device **100**.

[0077] As shown in FIG. **3**, in the cyclone integrated type storage device **100**, the feeding pipe **125** is connected to the particle storage chamber **112** at a position below the particle diffusion space S**1** and above the particle accumulation space S**2**.

[0078] The distance between the lower end of the particle diffusion space S**1** and the upper end of the particle accumulation space S**2** is equal to an opening diameter D of the connection port **125***a* of the feeding pipe **125** facing the particle storage chamber **112**. In other words, the connection port **125***a* of the feeding pipe **125** is located at a boundary between the lower end of the particle diffusion space S**1** and the upper end of the particle accumulation space S**2**

[0079] Further, it is preferable that an end **125***b* of the feeding pipe **125** at least on the connection port **125***a* side thereof be connected to the pressure vessel **110** at an inclination angle θ of 20° or more relative to a horizontal direction. This causes the char (fine particles) supplied through the feeding pipe **125** to fall down below the lower end of the particle diffusion space S**1** of the particle storage chamber **112**. This prevents the char from flying or rediffusing, allowing accumulation of the char in the particle accumulation space S**2**.

[0080] It is preferable that assist gas be sent into the feeding pipe **125** from the lower side of the feeding pipe **125** to facilitate flow of the char within the feeding pipe **125**.

[0081] Then, an explanation will be given of a method to separate the char from the produced gas by the cyclone integrated type storage device **100** that is vertically disposed as described above.

[0082] In separating the char from the produced gas by the cyclone integrated type storage device **100**, the produced gas containing the char is first introduced from the outside (from the gas generation line **49**) into the cyclone **101** provided in the upper area of the pressure vessel **110**. The produced gas is swirled in the cyclone **101**, which results in at least some of the char being separated from the produced gas. The char separated within the cyclone **101** is discharged downward through the opening **102** formed at the lower end of the cyclone **101**. The char discharged downward through the opening **102** is stored in the particle storage chamber **112** provided in the lower part of the pressure vessel **110**. The char stored in the particle storage chamber **112** is discharged outside through the outlet port **113** formed in the bottom of the pressure vessel **110**.

[0083] The above-described cyclone integrated type storage device **100** includes the cyclone **101** for separating char from gas in the upper part of the pressure vessel **110** in which the particle storage chamber **112** is provided. This eliminates the need for separately providing the cyclone **101** and a container (bin) for storing the char. This in turn eliminates the need for a pipe to connect the cyclone **101** and the container (bin) and an expansion member required for the pipe connection, and thus simplifies the equipment configuration, helping to reduce equipment costs.

[0084] Since the cyclone **101** is contained in the pressure vessel **110**, the cyclone **101** itself does not need to have a shape, wall thickness or seal structure that ensures its pressure resistance. In this respect too, equipment costs can be reduced.

[0085] Further, the cyclone integrated type storage device **100** includes the equalization pipe **118**. Thus, when the char separated by the cyclone **101** falls down into the particle storage chamber **112** located vertically below the cyclone **101**, the produced gas present in the particle storage chamber **112** is pushed out into the equalization pipe **118** by the amount equal to the volume of the fallen char. The produced gas having flowed into the equalization pipe **118** can be sent into the flow path **105***a* of the exhaust pipe **105**. This allows evening out the pressure between the inside of the pressure vessel **110** and the inside of the flow path **105***a* of the gas discharged from the exhaust port **103**.

[0086] The equalization pipe **118** communicates with the pressure vessel **110** at the position vertically above the opening **102** of the cyclone **101**. This prevents the fallen char separated by the cyclone **101** from flying or rediffusing into the equalization pipe **118**.

[0087] Further, the feeding pipe **125** for sending the char captured by the porous filter **120** to the particle storage chamber **112** is connected to the particle storage chamber **112** at the position vertically below the particle diffusion space S**1** and vertically above the particle accumulation space S**2**. Connecting the feeding pipe **125** at the position below the particle diffusion space S**1** in this way allows the char discharged from the feeding pipe **125** to move downward along with the flow F**2** of the gas in the particle diffusion space S**1**. This prevents the char from flying or rediffusing upward. The flow of fine particles transported through the feeding pipe **125** and the flow F**2** from the opening **102** also prevent the char accumulated in the particle accumulation space S**2** from flying or rediffusing upward.

[0088] The distance between the lower end of the particle diffusion space S**1** and the upper end of the particle accumulation space S**2** is made equal to the opening diameter D of the connection port **125***a* of the feeding pipe **125** facing the particle storage chamber **112**. This appropriately minimizes the size of the boundary between the lower end of the particle diffusion space S**1** and the upper end of the particle accumulation space S**2**. This prevents the cyclone integrated type storage device **100** from increasing its vertical size.

[0089] At least one end **125***b* of the feeding pipe **125** on the connection port **125***a* side thereof, which is relative to an end facing a vertically lower part of the porous filter **120**, is inclined obliquely downward at an angle of 20° or more relative to the horizontal direction. This large inclination of the feeding pipe **125** allows stable transportation of the char (fine particles) through the feeding pipe **125**, which results in the supplied char (fine particles) falling down into the particle accumulation space S**2** in the lower part of the particle storage chamber **112**. This prevents the char from flying or rediffusing into the particle diffusion space S**1** and flowing into the equalization pipe **118**, and allows accumulation of the char in the particle accumulation space S**2**. When at least one end **125***b* of the feeding pipe **125** on the connection port **125***a* side thereof is inclined at a smaller angle, which is at least 20°, relative to the horizontal direction, the porous filter **120** can be placed closer to the pressure vessel **110**. On the other hand, when at least one end **125***b* of the feeding pipe **125** on the connection port **125***a* side thereof is inclined at an angle larger than 20° relative to the horizontal direction, the porous filter **120** can be placed vertically above the pressure vessel **110** of the cyclone integrated type storage device **100**, and this prevents interference between the porous filter **120** and the pressure vessel **110**. Thus, the inclination angle of at least one end **125***b* of the feeding pipe **125** on the connection port **125***a* side thereof may be optionally selected from angles of 20° or more relative to the horizontal direction. This improves flexibility in the layout of the cyclone integrated type storage device **100** and the porous filter **120**, helping to downsize the char recovery unit **15**.

[0090] Although the above embodiment has described, by way of example, the IGCC system including a coal gasifier that produces a combustible gas from pulverized coal, the gasification unit of the present invention is applicable to gasification of other carbonaceous feedstocks such as biomass fuels, which include timber from forest thinning, waste wood, driftwood, grasses, waste, sludge, and tire. Further, use of the gasification unit of the present invention is not limited to power generation; the gasification unit can be used in a chemical plant gasifier to obtain desired chemical substances.

[0091] In the above embodiment, coal is used as a fuel, and the coal may be either high-grade or low-grade. Further, the fuel is not limited to the coal, and may be a biomass fuel that is used as recyclable, biological organic resources. Examples of the biomass fuel include timber from forest thinning, waste wood, driftwood, grasses, waste, sludge, tire, and recycled fuels (e.g., pellets and chips) made from these resources.

REFERENCE SIGNS LIST

[0092] **10** Integrated coal gasification combined cycle (integrated gasification combined cycle)
[0093] **11** Coal feeder
[0094] **11***a* Coal feeding line
[0095] **14** Gasification unit
[0096] **15** Char recovery unit
[0097] **16** Gas purification unit
[0098] **17** Gas turbine
[0099] **18** Steam turbine
[0100] **19** Generator
[0101] **20** Heat recovery steam generator
[0102] **41** Compressed air supply line
[0103] **42** Air separation unit
[0104] **43** First nitrogen supply line
[0105] **45** Second nitrogen supply line
[0106] **46** Char return line
[0107] **47** Oxygen supply line
[0108] **48** Foreign object remover
[0109] **49** Gas generation line
[0110] **51** Dust collector
[0111] **52** Char supply hopper
[0112] **53** Gas discharge line
[0113] **61** Compressor
[0114] **62** Combustor
[0115] **63** Turbine
[0116] **64** Rotary shaft
[0117] **65** Compressed air supply line
[0118] **66** Fuel gas supply line
[0119] **67** Combustion gas supply line
[0120] **68** Booster
[0121] **69** Turbine
[0122] **70** Flue gas line
[0123] **71** Steam supply line
[0124] **72** Steam recovery line
[0125] **73** Condenser
[0126] **74** Gas cleaning unit
[0127] **75** Stack
[0128] **100** Cyclone integrated type storage device
[0129] **101** Cyclone
[0130] **101***a* Cylindrical part
[0131] **101***b* Tapered part
[0132] **101***c* Plate
[0133] **101***s* Surrounding wall
[0134] **102** Opening
[0135] **103** Exhaust port
[0136] **105** Exhaust pipe
[0137] **105***a* Flow path
[0138] **110** Pressure vessel
[0139] **111** Cyclone chamber
[0140] **111***t* Top
[0141] **112** Particle storage chamber
[0142] **112***b* Bottom
[0143] **112***f* Inner surface
[0144] **113** Outlet port
[0145] **114** Widened part
[0146] **116** Char supply pipe
[0147] **118** Equalization pipe
[0148] **120** Porous filter (filter)
[0149] **125** Feeding pipe
[0150] **125***a* Connection port
[0151] **125***b* End
[0152] **S1** Particle diffusion space
[0153] **S2** Particle accumulation space
[0154] θ Inclination angle

1-9. (canceled)

10. A cyclone integrated type storage device comprising:
a hollow pressure vessel;
a cylindrical cyclone chamber formed in a vertically upper part of the pressure vessel;
a cyclone provided within the cyclone chamber, the cyclone being configured to swirl gas introduced from outside and containing particles to thereby separate at least some of the particles from the gas, the cyclone including an opening and an exhaust port, the opening permitting discharge of the separated particles vertically downward in the pressure vessel, the exhaust port permitting discharge of the gas to the outside of the pressure vessel;
a cylindrical particle storage chamber formed in a vertically lower part of the pressure vessel, the particle storage chamber storing the particles discharged through the opening, the particle storage chamber having a lager inner diameter than an inner diameter of the cyclone chamber; and
an outlet port formed in a bottom of the pressure vessel, the outlet port permitting discharge of the particles stored in the particle storage chamber to the outside.

11. The cyclone integrated type storage device according to claim **10**, further comprising an equalization pipe configured to communicate between an inside of the pressure vessel and an inside of a flow path of the gas discharged from the exhaust port.

12. The cyclone integrated type storage device according to claim **11**, wherein the equalization pipe communicates with the inside of the pressure vessel at a position vertically above the opening.

13. The cyclone integrated type storage device according to claim **10**, wherein the particle storage chamber comprises:
a particle diffusion space in which a flow of the particles discharged through the opening gradually diffuses radially outward in the particle storage chamber, a lower boundary of the particle diffusion space coinciding with a position at which the diffusing particles hit an inner surface of the particle storage chamber; and
a particle accumulation space formed vertically below the particle diffusion space, the particle accumulation space permitting accumulation of the particles on the bottom of the pressure vessel.

14. The cyclone integrated type storage device according to claim **13**, further comprising a feeding pipe that is connected to a filter that captures fine particles unseparated from the gas in the cyclone and discharged through the exhaust port along with the gas and that is configured to send the fine particles captured by the filter into the particle storage chamber,
wherein the feeding pipe communicates with the particle storage chamber at a position vertically below the particle diffusion space and vertically above the particle accumulation space.

15. The cyclone integrated type storage device according to claim **14**, wherein a distance between a lower end of the particle diffusion space and an upper end of the particle accumulation space is equal to an opening diameter of a connection port of the feeding pipe facing the particle storage chamber.

16. The cyclone integrated type storage device according to claim **14**, wherein an end of the feeding pipe on a connection port side thereof facing the particle storage chamber is inclined obliquely downward at 20° or more relative to a horizontal direction.

17. A gasification combined power generating device comprising the cyclone integrated type storage device according claim **10**.

18. A method for separating particles in the cyclone integrated type storage device according to claim **10**, the method comprising:

introducing gas containing the particles from outside into the cyclone provided in the vertically upper part of the pressure vessel, and swirling the gas to thereby separate at least some of the particles from the gas;

discharging the particles separated in the cyclone vertically downward through the opening formed at a lower end of the cyclone;

storing the particles discharged downward through the opening in the particle storage chamber provided in the vertically lower part of the pressure vessel; and

discharging the particles stored in the particle storage chamber to the outside through the outlet port formed in the bottom of the pressure vessel.

19. The cyclone integrated type storage device according to claim **14**, wherein the filter is provided at a position lateral to the cyclone chamber and above the particle storage chamber.

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