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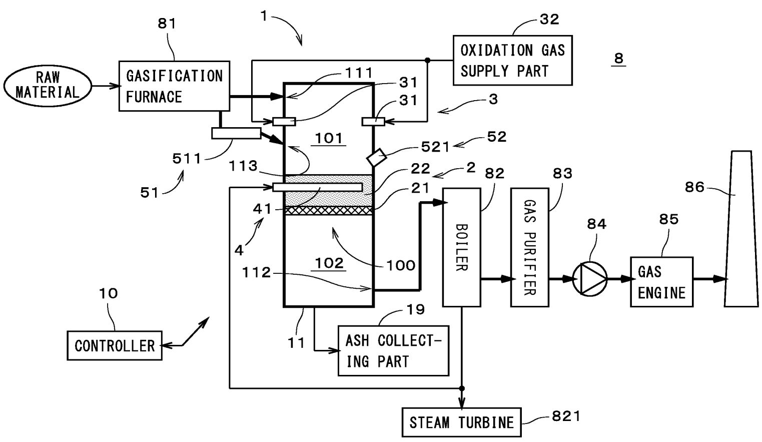
(54) GAS REFORMER FURNACE

(57) In a gas reforming furnace (1), a furnace body (11) forms a flow path (100) for a pyrolysis gas supplied from a gasification furnace (81). A filled layer retainer (2) is provided in the flow path (100) and retains a char filled layer (22) filled with char. A tar combustor (3) supplies an oxygen-containing gas to the pyrolysis gas in a space upstream of the char filled layer (22) in the flow path (100) to burn tar contained in the pyrolysis gas before the pyrolysis gas passes through the char filled layer (22). A steam ejector (4) ejects steam from an ejection port provided inside the char filled layer (22). Accordingly, the concentration of tar in the pyrolysis gas can be reduced significantly.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a gas reforming furnace.

Background Art

[0002] Gasification of carbon-containing raw materials such as biomass has conventionally been performed. In the gasification of a raw material, the raw material is cracked by heat at a temperature of 500 to 800°C in a gasification furnace to generate a pyrolysis gas. The pyrolysis gas contains not only gas but also other substances such as tar vapor and powdered char. The pyrolysis gas is transmitted to a downstream gas reforming furnace. Inside the gas reforming furnace, a high temperature condition at 1000°C or above is kept by partial combustion caused by oxygen supply, heating with a high-temperature gas, or heating with a heater, and water steam is blown into the furnace. Therefore, tar and char contained in the pyrolysis gas are reformed with steam and converted to a fuel gas such as hydrogen (H2) or carbon monoxide (CO). The reformed pyrolysis gas is subjected to, for example, impurity removal in a gas purifier and then used for power generation in an internal combustion engine such as a gas engine.

[0003] Japanese Patent Application Laid-Open No. 2007-177106 discloses a biomass gasification apparatus. In this apparatus, a gasification unit includes a first accumulator that temporarily accumulates char flowing downwardly from a thermal cracking unit and guides the char downwardly, a first oxidation gas supply part that introduces an oxidation gas such as air into a downflow passage that communicates with the first accumulator, a second accumulator that temporarily accumulates char flowing downwardly from the downflow passage, a gas extraction port formed at the top of the second accumulator, and a second oxidation gas supply part that introduces an oxidation gas such as air into the second accumulator. In the apparatus, a pyrolysis gas with a tar content flows through the downflow passage toward the gas extraction port. The air supplied from the first oxidation gas supply part causes combustion reactions of the char and the pyrolysis gas, and this results in a rise in the temperature of the downflow passage. Accordingly, the tar contained in the pyrolysis gas is cracked by heat and gasified. On the other hand, the char flowing downwardly into the second accumulator causes combustion reactions with the air supplied from the second oxidation gas supply part, and this produces a combustion gas composed primarily of carbon dioxide and steam. The combustion gas reacts with the char when moving upward toward the gas extraction port and generates carbon monoxide and hydrogen.

[0004] Japanese Patent Application Laid-Open No. 2007-231063 discloses a gasification apparatus for gasifying char and cracking tar by passing a pyrolysis gas through a char filled layer in a fixed-bed gasification furnace that accumulates the char filled layer at the bottom. The apparatus also includes an air nozzle for ejecting compressed air into the char filled layer, and prevents the occurrence of blow-by in the char filled layer by controlling the air nozzle on the basis of temperatures upstream and downstream of the char filled layer.

[0005] With the above-described techniques for simply blowing oxygen and steam into the gas reforming furnace, the tar in the pyrolysis gas may not be cracked sufficiently inside the furnace. In this case, the remaining tar may adversely affect processing performed in the gas purifier and power generation in the gas engine. Thus, there is demand for techniques for significantly reducing the concentration of tar in the pyrolysis gas.

Summary of Invention

[0006] The present invention is intended for a gas reforming furnace for reforming a pyrolysis gas supplied from a gasification furnace, and it is an object of the present invention to significantly reduce the concentration of tar in the pyrolysis gas.

[0007] The gas reforming furnace according to the present invention includes a furnace body forming a flow path for the pyrolysis gas, a filled layer retainer provided in the flow path and retaining a char filled layer filled with char, a tar combustor that supplies an oxygen-containing gas to the pyrolysis gas in a space upstream of the char filled layer in the flow path to burn tar contained in the pyrolysis gas before the pyrolysis gas passes through the char filled layer, and a steam ejector that ejects steam from an ejection port provided inside the char filled layer or in proximity to the char filled layer.

[0008] According to the present invention, the concentration of tar in the pyrolysis gas can be reduced significantly.

[0009] In a preferable embodiment of the present invention, the filled layer retainer may include a retaining member that has a plurality of holes and retains the char filled layer from underside.

[0010] In another preferable embodiment of the present invention, the gas reforming furnace may further include a char supply part that supplies char to the filled layer retainer, a layer-thickness acquisition part that acquires a thickness of the char filled layer, and a controller that controls an amount of char supplied by the char supply part, on the basis of the thickness.

[0011] In yet another preferable embodiment of the present invention, a length of the tar combustor from a supply position of the oxygen-containing gas to a surface of the char filled layer in a direction of flow of the pyrolysis gas may be greater than the thickness of the char filled layer.

[0012] In yet another preferable embodiment of the present invention, a temperature in a space downstream of the char filled layer in the flow path may be lower than a temperature in the char filled layer.

[0013] These and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

Brief Description of Drawings

[0014]

Fig. 1 illustrates a configuration of a gasification system;
Fig. 2 illustrates a configuration of a steam ejector;
Fig. 3 illustrates a configuration of the steam ejector;
Fig. 4 illustrates a configuration of an experimental apparatus;
Fig. 5 illustrates experimental results;
Fig. 6 illustrates another example of the steam ejector;
Fig. 7 illustrates another example of the steam ejector; and
Fig. 8 illustrates another example of the steam ejector.

Description of Embodiments

[0015] Fig. 1 illustrates a configuration of a gasification system 8 according to an embodiment of the present invention. The gasification system 8 includes a gasification furnace 81, a gas reforming furnace 1, a boiler 82, a gas purifier 83, an induced draft fan 84, a gas engine 85, and a smokestack 86. The gasification system 8 forms an overall flow path that passes through the gasification furnace 81, the gas reforming furnace 1, the boiler 82, the gas purifier 83, the induced draft fan 84, the gas engine 85, and the smokestack 86 in the order mentioned. By driving the induced draft fan 84, a later-described pyrolysis gas generated in the gasification furnace 81 flows toward the smokestack 86 through the overall flow path.

[0016] The gasification furnace 81 is, for example, a kiln-type gasification furnace, a fixed-bed gasification furnace, or a fluidized-bed gasification furnace, and wastes or biomass (hereinafter, simply referred to as "raw materials") are input in the gasification furnace 81. Examples of the raw materials include non-industrial wastes, industrial wastes, sludge, and woody biomass. The raw materials are cracked and gasified by being heated at a temperature of, for example, 400 to 800°C. This generates a pyrolysis gas. The pyrolysis gas contains not only gas but also other substances such as tar vapor and powdered char. The pyrolysis gas is supplied to the gas reforming furnace 1. At the bottom of the gasification furnace 81, a char recovery part (not shown) is provided and recovers char that is not included in the pyrolysis gas. The char that has been recovered (hereinafter, referred to as "recovered char") is supplied via a later-described screw feeder 511 into a furnace body 11 of the gas reforming furnace 1.

[0017] The gas reforming furnace 1 performs, for example, reforming of carbon-containing non-gas components such as tar and char contained in the pyrolysis gas. The configuration of the gas reforming furnace 1 will be described later. The pyrolysis gas reformed by the gas reforming furnace 1 (hereinafter referred to as "reformed gas") flows into the boiler 82. In the boiler 82, the temperature of the reformed gas drops as a result of heat exchange with circulating water that circulates inside the boiler 82. The reformed gas flows from the boiler 82 into the gas purifier 83. The gas purifier 83 performs purification processing such as removal of dust and mist, dechlorination, and desulfurization on the reformed gas. The reformed gas that has undergone the purification processing has a temperature of approximately 50°C, for example, and is supplied to the gas engine 85 via the induced draft fan 84. The gas engine 85 generates electric power using the reformed gas as a fuel. An exhaust gas obtained by burning the reformed gas in the gas engine 85 is exhausted to the atmosphere through the smokestack 86.

[0018] The circulating water in the boiler 82 turns into steam as a result of heat exchange with the reformed gas. Part of the steam is supplied to a later-described steam ejector 4 of the gas reforming furnace 1. The remaining steam is used to drive a steam turbine 821 and thereafter returned to the inside of the boiler 82 to serve as the circulating water. The aforementioned steam may be supplied to the gasification furnace 81 and used to heat the raw materials.

[0019] The gas reforming furnace 1 includes the furnace body 11, a filled layer retainer 2, a char supply part 51, a layer-thickness acquisition part 52, a tar combustor 3, the steam ejector 4, and a controller 10. The controller 10 performs overall control of the gas reforming furnace 1. The controller 10 may perform overall control of the gasification system 8.

[0020] The furnace body 11 has, for example, a generally cylindrical shape. One end portion of the furnace body 11 has an inlet 111 connected to the gasification furnace 81. The other end portion has an outlet 112 connected to the boiler 82. The pyrolysis gas from the gasification furnace 81 flows through the inlet 111 into the furnace body 11. The pyrolysis gas flows through the inside of the furnace body 11 toward the outlet 112 and flows out to the boiler 82 through the outlet 112. In this way, the furnace body 11 forms a flow path 100 for the pyrolysis gas. The shape of the furnace body 11 may be appropriately changed and may, for example, be a U-shape.

[0021] The filled layer retainer 2 includes a plate-like retaining member 21 provided in the flow path 100. The retaining member 21 extends approximately perpendicular to the direction of flow of the pyrolysis gas from the inlet 111 to the outlet 112 (hereinafter, referred to as a "gas flow direction") and is connected to the entire periphery of the side wall of the furnace body 11. In the present embodiment, the gas flow direction is parallel to the vertical direction. The retaining member 21 has a plurality (large number) of uniformly dispersed holes, and the pyrolysis gas passes through these holes. The retaining member 21 is made of, for example, ceramics, porcelain, a refractory material, concrete, or a metal. On the retaining member 21, char is accumulated. In other words, the char filled layer 22 filled with char is provided on the retaining member 21. The char filled layer 22 extends over the entire upper face of the retaining member 21. The char filled layer 22 is retained from the underside by the retaining member 21.

[0022] The char supply part 51 includes the screw feeder 511. One end of the screw feeder 511 is connected to the char recovery part of the gasification furnace 81. The other end of the screw feeder 511 is connected to the furnace body 11 of the gas reforming furnace 1. The furnace body 11 has a char supply port 113 between the filled layer retainer 2 and the inlet 111. When the screw feeder 511 is driven, the recovered char is transported from the char recovery part to the char supply port 113 and supplied to the filled layer retainer 2. In the gas reforming furnace 1, the controller 10 controls the screw feeder 511 so as to adjust the supply amount of the recovered char (feed speed of the recovered char). The char supply part 51 may include a powder feeder such as a table feeder other than the screw feeder 511 and supply the recovered char via a chute to the filled layer retainer 2. Depending on the structures of the gasification furnace 81 and the gas reforming furnace 1, the bottom of the gasification furnace 81 may be connected to the upper portion of the furnace body 11 so that the recovered char can simply drop from the bottom and be supplied to the filled layer retainer 2. In this case, for example, a mechanism (e.g., gate) for adjusting the amount of the recovered char that drops from the bottom of the gasification furnace 81 may be provided.

[0023] The layer-thickness acquisition part 52 includes a level sensor 521. The level sensor 521 is of a laser type and detects a height of the surface (upper face in Fig. 1) of the char filled layer 22. A detection value obtained by the level sensor 521 is output to the controller 10. In actual practice, a distance between the retaining member 21 of the filled layer retainer 2 and the surface of the char filled layer 22, i.e., the thickness of the char filled layer 22 (hereinafter, referred to as a "layer thickness"), is acquired by detecting the height of the surface of the char filled layer 22. The controller 10 controls the amount of recovered char supplied from the char supply part 51 to the filled layer retainer 2 on the basis of the acquired layer thickness. In actual practice, the supply amount of the recovered char is controlled so as to keep the layer thickness at a constant value.

[0024] As described previously, since the char supply part 51 refills the char filled layer 22 with the recovered char by ejection from the char supply port 113, the char filled layer 22 has a contoured surface. This is, however, not a problem in the present processing example because a strictly exact layer thickness is not an absolute necessity. Of course, an accurate layer thickness may be obtained by providing a plurality of level sensors 521 and obtaining an average value of detection values obtained from these level sensors. The layer-thickness acquisition part 52 may acquire the layer thickness by obtaining a difference in pressure between a position upstream of the char filled layer 22 and a position downstream of the char filled layer 22.

[0025] In the case where the amount of char generated in the gasification furnace 81 is excessively greater than the amount of recovered char supplied by the char supply part 51 to the filled layer retainer 2, the recovered char may be discharged to the outside via a gate or the like, which is not shown. In this case, the recovered char discharged to the outside may be input again into the gasification furnace 81 in order to improve efficiency in the gasification of the raw materials. On the other hand, in the case where the amount of char generated in the gasification furnace 81 is insufficient as the supply amount of char to be supplied to the filled layer retainer 2, other supplementary substances such as charcoal, coal, or activated carbon may be supplied to the filled layer retainer 2. Note that the ratio of char generated from the raw materials depends on the heating temperature in the gasification furnace 81. For example, in the case of a kiln-type gasification furnace 81 as one example, when the heating temperature is 400°C, the ratio of char generated from the raw materials is approximately 50%, and when the heating temperature is 600°C, the ratio of the char is approximately 30%. In this way, the ratio of char generated from the raw materials decreases as the heating temperature in the gasification furnace 81 increases.

[0026] The tar combustor 3 includes a plurality of oxidation gas nozzles 31 and an oxidation gas supply part 32. The oxidation gas nozzles 31 are disposed in a space 101 upstream of the char filled layer 22 in the flow path 100 (i.e., space on the side close to the inlet 111 when viewed from the char filled layer 22; hereinafter simply referred to as an "upstream space 101"). The oxidation gas supply part 32 supplies an oxygen-containing gas (hereinafter, referred to as an "oxidation gas") to the oxidation gas nozzles 31. The oxidation gas is, for example, air. The oxidation gas may be oxygen itself. The oxidation gas supplied from the oxidation gas supply part 32 is ejected into the upstream space 101 by the oxidation gas nozzles 31. In the tar combustor 3, the oxidation gas nozzles 31 may be provided on the side wall of the furnace body 11 in multiple stages in the gas flow direction. As another alternative, the oxidation gas nozzles 31 may be provided in the upper face portion of the furnace body 11.

[0027] Figs. 2 and 3 illustrate a configuration of the steam ejector 4. Fig. 2 illustrates a section of the furnace body 11 that is perpendicular to the gas flow direction at a position of a later-described steam pipe 41 (section viewed from the inlet 111), and Fig. 3 illustrates a section of the furnace body 11 that is parallel to the gas flow direction. The steam ejector 4 includes the steam pipe 41, and the steam supplied from the boiler 82 flows through the steam pipe 41. The steam pipe 41 has a plurality of folded portions folded into U-shapes in a plane perpendicular to the gas flow direction. The folded portions are disposed inside the furnace body 11, and more specifically, inside the char filled layer 22. A portion of the steam pipe 41 that is disposed inside the furnace body 11 has a plurality of ejection ports 411. In the example in Fig. 3, the ejection ports 411 are open on the opposite side to the retaining member 21, i.e., open toward the upstream space 101. The steam ejector 4 ejects steam from the ejection ports 411. The temperature of the steam is, for example, approximately 300°C. In Fig. 3, the ejection direction of the steam from each ejection port 411 is indicated by an arrow with the reference sign A1.

[0028] The length of the portion of the steam pipe 41 that is disposed inside the furnace body 11 is preferably greater than or equal to the diameter of the furnace body 11, and more preferably greater than or equal to two times the diameter of the furnace body 11. This makes it easy to dispersively eject steam over a wide range of a plane perpendicular to the gas flow direction. The length of this portion is, for example, less than or equal to 10 times the diameter of the furnace body 11. The ejection ports 411 may be open toward the retaining member 21. The steam supplied to the steam pipe 41 may be generated using heat of the exhaust gas from the gas engine 85 or an external heat source.

[0029] In the gas reforming furnace 1 in Fig. 1, the pyrolysis gas supplied from the inlet 111 to the inside of the furnace body 11 (flow path 100) flows toward the char filled layer 22 in the upstream space 101. In the upstream space 101, an oxidation gas is supplied to the pyrolysis gas by the oxidation gas nozzles 31, and not only the gas contained in the pyrolysis gas but also tar vapor are partially combusted. Continuous partial combustion of the pyrolysis gas allows the upstream space 101 to be kept at a high temperature, and the temperature in the upstream space 101 is, for example, in the range of 800 to 1200°C. In this way, the tar combustor 3 burns the tar contained in the pyrolysis gas and reduces the concentration of tar before the pyrolysis gas reaches the char filled layer 22. The tar combustor 3 may also cause other reactions in addition to the combustion reactions.

[0030] From the viewpoint of ensuring sufficient space for tar combustion, the length of the tar combustor 3 from the supply position of the oxidation gas (here, the oxidation gas nozzle 31 that is located farthest from the char filled layer 22) to the surface of the char filled layer 22 in the gas flow direction is preferably greater than the thickness of the char filled layer 22. Here, the position of the surface of the char filled layer 22 is, for example, an averaged position of this surface. More preferably, the length of the tar combustor 3 is greater than or equal to 1.5 times the thickness of the char filled layer 22. The length of the tar combustor 3 is, for example, less than or equal to 10 times the thickness of the char filled layer 22. Depending on the design of the gas reforming furnace 1, the length of the tar combustor 3 may be less than or equal to the thickness of the char filled layer 22.

[0031] The pyrolysis gas that has reached the char filled layer 22 flows through the interstices between pieces of recovery char in the char filled layer 22 and the holes of the retaining member 21 to a space 102 downstream of the char filled layer 22 in the flow path 100 (space on the side close to the outlet 112 when viewed from the char filled layer 22; hereinafter simply referred to as a "downstream space 102"). When the pyrolysis gas passes through the char filled layer 22, tar remaining in the pyrolysis gas and powdered char are collected (trapped) in, for example, pores of the recovery char in the char filled layer 22. The temperatures of the char filled layer 22 and the pyrolysis gas flowing in the char filled layer 22 become high due to the combustion of the pyrolysis gas in the upstream space 101. Moreover, steam is ejected vigorously (e.g., at a flow velocity higher than the flow velocity of the pyrolysis gas) from the ejection ports 411 (see Fig. 2) of the steam ejector 4 toward the recovered char in the char filled layer 22. As a result, the tar and the powdered char, which are collected in the recovered char, and the recovered char itself are converted (reformed) to a fuel gas such as hydrogen or carbon monoxide by steam reforming reaction. In the char filled layer 22, the recovered char accelerates the reforming reaction of the tar. That is, the recovered char can be regarded as playing a role as a catalyst.

[0032] The reformed pyrolysis gas, i.e., reformed gas, reaches the outlet 112 through the downstream space 102 and is exhausted to the boiler 82. Typically, no oxidation gas is supplied to the char filled layer 22 and the downstream space 102, and therefore no combustion reactions occur therein. The steam reforming reaction of the tar or the like is an endothermic reaction. Accordingly, the temperature in the downstream space 102 becomes, for example, less than 1200°C, which is lower than the temperatures in the upstream space 101 and the char filled layer 22.

[0033] When the recovered char is reduced in amount by reforming, the char filled layer 22 is refilled with new recovered char by the char supply part 51. Among residuals that induce no reforming reactions in the char filled layer 22, residuals that are smaller in size than the holes of the retaining member 21 drop downwardly from these holes. At the bottom of the furnace body 11, such residuals are collected by an ash collecting part 19.

[0034] Experimental examples will now be described. Fig. 4 illustrates a configuration of an experimental apparatus 9. In the experimental apparatus 9, a tubular container 91 with a bottom is filled with quartz beads 92, and mimic char is accumulated on the quartz beads 92 to form a char filled layer 93. The mimic char is charcoal powder. Disposed in the periphery of the tubular container 91 is an electric heater 97, and the tubular container 91 is heated to 1100°C. The tubular container 91 has a lid member 911 attached to the top, and the lid member 911 has an inlet 912. Through the inlet 912, mimic gas, mimic tar, steam, an oxygen gas, and mimic char can be supplied into the tubular container 91. The mimic gas contains components that exist in an actual pyrolysis gas, and the mimic gas is a mixed gas of N_2, CO_2, H_2, CO, and CH_4. The mimic tar is toluene. The oxygen gas is used for partial combustion of mimic gas or the like.

[0035] The lid member 911 includes a nozzle 94 (hereinafter, referred to as an "in-layer nozzle 94"). An ejection port at the tip end of the in-layer nozzle 94 is located inside the char filled layer 93, and more specifically, in the center of the char filled layer 93 in the up-down direction. Steam can be supplied to the in-layer nozzle 94. The lower end of the tubular container 91 has an outlet 913 for mimic gas or the like. Gas exhausted from the outlet 913 is introduced into a detector 95 (gas chromatograph) via a char collector 951 so as to detect the concentration of mimic tar in the gas.

[0036] In the experiment, mimic gas, mimic tar, and mimic char were supplied from the inlet 912 into the tubular container 91 under conditions shown in Table 1. Then, the concentration of mimic tar in the gas exhausted from the tubular container 91 was measured with the detector 95. At this time, in Case 1, an oxygen gas and steam were supplied from the inlet 912 to the tubular container 91 in the absence of the char filled layer 93. In Case 2, in the presence of the char filled layer 93, an oxygen gas and steam were supplied from the inlet 912 into the tubular container 91. In Case 3, in the presence of the char filled layer 93, an oxygen gas and steam were supplied from the ejection port of the in-layer nozzle 94 into the char filled layer 93. In Case 4, in the presence of the char filled layer 93, an oxygen gas was supplied from the inlet 912 into the tubular container 91, and steam was supplied from the ejection port of the in-layer nozzle 94 into the char filled layer 93. The same amounts of the oxygen gas and the steam were supplied in any of these cases.

Table 1

		Case 1	Case 2	Case 3	Case 4
Char filled layer		Absent	Present	Present	Present
In-layer nozzle		Absent	Absent	Present	Present
Nozzle medium		Absent	Absent	$H_2O + O_2$	H_2O
Experimental time	h	1			
Reforming temperature	°C	1100			
Amount of mimic gas	L/min	0.7			
Amount of mimic tar	g/min	0.07			
Amount of mimic char	g/min	0.13			
Supply amount of steam	L/min	0.8			

[0037] Fig. 5 illustrates experimental results. It can be seen from Fig. 5 that, compared to any of Cases 1 to 3, Case 4 has achieved a significantly reduced concentration of mimic tar and a high cracking rate (reforming rate) of the mimic tar. In Case 4, since the oxygen gas was supplied from the inlet 912 into the tubular container 91, the mimic gas and the mimic tar (pyrolysis gas) were burnt before passing through the char filled layer 93 as in the tar combustor 3 of the gas reforming furnace 1 in Fig. 1. Also, as in the case of the filled layer retainer 2 and the steam ejector 4, unburnt mimic tar was collected in the char filled layer 93, and the mimic tar and the mimic char were reformed with the steam ejected from the ejection port of the in-layer nozzle 94 into the char filled layer 93.

[0038] As described above, the gas reforming furnace 1 includes the tar combustor 3, the filled layer retainer 2, and the steam ejector 4. The tar combustor 3 burns the tar contained in the pyrolysis gas before the pyrolysis gas passes through the char filled layer 22. The char filled layer 22 collects the tar remaining in the pyrolysis gas, and the steam ejector 4 ejects steam from the ejection ports 411 provided inside the char filled layer 22, so that the tar and the char are reformed with the steam in the char filled layer 22. This enables appropriately reforming the pyrolysis gas and appropriately gasifying the recovered char, as well as significantly reducing the concentration of tar in the pyrolysis gas. As a result, the load of the gas purification processing on the gas purifier 83 can be reduced, and the occurrence of troubles due to the remaining tar in the gas engine 85 can be reduced.

[0039] By the way, it is also possible to use a common catalyst to reform the tar in the pyrolysis gas. However, in this case, it is necessary to install a dust collector between the gasification furnace and the gas reforming furnace in order to prevent the catalyst from being clogged with char and dust contained in the pyrolysis gas. In the case where wastes are used as raw materials, acid gas components such as sulfur (S) and chlorine (Cl) in the wastes can poison and deactivate the catalyst. Thus, long-term use of the catalyst is difficult, and exchange of the catalyst is necessary. This increases running costs of the gas reforming furnace.

[0040] In contrast, in the gas reforming furnace 1, the recovered char generated in the gasification furnace 81 is used to form the char filled layer 22, and the char filled layer 22 is used for tar reforming. The recovered char of the char filled layer 22 is also reformed (gasified). As a result, the energy of the raw materials can be used without waste. Also, since there is no need to use the aforementioned catalyst that requires exchange, running costs of the gas reforming furnace 1 can also be reduced.

[0041] In the gas reforming furnace 1, the thickness of the char filled layer 22 can be kept constant with high precision by controlling the amount of recovered char supplied by the char supply part 51 on the basis of the layer thickness acquired by the layer-thickness acquisition part 52. As a result, it is possible to appropriately maintain the space (upstream space 101) necessary for tar combustion and the thickness of the char filled layer 22 required for tar collection and to stably reduce the concentration of tar in the pyrolysis gas. Also, the char filled layer 22 can be retained appropriately since the filled layer retainer 2 includes the retaining member 21 having a plurality of holes.

[0042] Fig. 6 illustrates another example of the steam ejector 4. The steam ejector 4 in Fig. 6 includes a plurality of steam nozzles 41a. The steam nozzles 41a are arranged at equiangular intervals in the circumferential direction about a central axis J1 of the furnace body 11 in a plane perpendicular to the gas flow direction. Each steam nozzle 41a has an ejection port 411 at the tip end. In Fig. 6, the ejection direction of the steam from each steam nozzle 41a is indicated by an arrow with the reference sign A2. In the example in Fig. 6, the ejection directions of the steam nozzles 41a are set such that the trajectories of the steam ejected from the steam nozzles 41a form parallel crosses. From the viewpoint of supplying steam over a wide range of a plane perpendicular to the gas flow direction (in other words, efficiently diffusing steam) within the char filled layer 22 in which steam is difficult to diffuse, it is preferable that the steam ejector 4 has three or more ejection ports 411 that are disposed at the same position in the gas flow direction as illustrated in Figs. 2 and 6.

[0043] Fig. 7 illustrates another example of the steam ejector 4. The steam ejector 4 in Fig. 7 includes a plurality of (two in Fig. 7) steam pipes 41 provided with an interval therebetween in the gas flow direction. This enables supplying steam over a wide range in the gas flow direction within the char filled layer 22. As a result, the concentration of tar in the pyrolysis gas can be further reduced. Of course, it is also possible to provide three or more steam pipes 41 with an interval therebetween in the gas flow direction. Alternatively, a plurality of steam nozzles 41a may be disposed with an interval therebetween in the gas flow direction.

[0044] The ejection ports 411 of the steam ejector 4 may be provided outside the char filled layer 22 as long as the ejection ports 411 are located in proximity to the char filled layer 22. In the example in Fig. 8, the steam pipe 41 is provided at a position slightly spaced from the surface of the char filled layer 22. This steam pipe 41 has a plurality of ejection ports 411 that are open downwardly, i.e., toward the char filled layer 22, in Fig. 8. Steam from the ejection ports 411 is ejected to the surface of the char filled layer 22 (see arrows A3 that indicate the ejection directions of the steam). In this case as well, tar and char can be reformed efficiently in the char filled layer 22. Here, the distance between the ejection ports 411 disposed in proximity to the char filled layer 22 and the surface of the char filled layer 22 is preferably less than or equal to one-third of the distance between the ejection ports 411 and the oxidation gas nozzle 31, and more preferably less than or equal to one-fifth of that distance. In this case, steam can be regarded as being ejected directly from the ejection ports 411 to the char filled layer 22.

[0045] The gasification system 8 and the gas reforming furnace 1 described above can be modified in various ways.

[0046] In addition to the oxidation gas, steam may also be introduced at a position distant from the char filled layer 22 in the upstream space 101. It is, however, noted that the flow rate of the oxidation gas is preferably higher than the flow rate of the steam, and more preferably no steam is introduced, in order to appropriately burn the tar contained in the pyrolysis gas in the upstream space 101. Also, an oxidation gas may be ejected inside or in proximity to the char filled layer 22, in addition to steam. In this case as well, the flow rate of the steam is preferably higher than the flow rate of the oxidation gas, and more preferably no oxidation gas is ejected, in order to appropriately reform the tar with the steam in the char filled layer 22.

[0047] From the viewpoint of broadening the range of the char filled layer 22 in the gas flow direction in which tar and char cause steam reforming reactions, at least one of the ejection ports 411 of the steam ejector 4 is preferably located at a position spaced by a distance greater than or equal to one-third of the thickness of the char filled layer 22 from the retaining member 21 toward the upstream side, and more preferably located at a position spaced by a distance greater than or equal to a half of that thickness.

[0048] Depending on the design of the gas reforming furnace 1, the retaining member 21 of the filled layer retainer 2 may be provided in proximity to the outlet 112. As another alternative, the char filled layer 22 may be retained at the bottom of the furnace body 11. In this case, the bottom plays a role as the filled layer retainer 2. The pyrolysis gas that has passed through the char filled layer 22 is exhausted out of the furnace body 11 through the outlet 112 provided at the bottom.

[0049] The reformed pyrolysis gas reformed by the gas reforming furnace 1 (i.e., reformed gas) may be used in a gas turbine or a fuel cell (e.g., solid oxide fuel cell (SOFC)). The reformed gas may be used as a fuel gas in various applications, and may also be used as a liquid fuel after conversion to a liquid.

[0050] The configurations of the above-described preferred embodiments and variations may be appropriately combined as long as there are no mutual inconsistencies.

[0051] While the invention has been shown and described in detail, the foregoing description is in all aspects illustrative and not restrictive. It is therefore to be understood that numerous modifications and variations can be devised without departing from the scope of the invention.

Reference Signs List

[0052]

1	Gas reforming furnace
2	Filled layer retainer
3	Tar combustor
4	Steam ejector
10	Controller
11	Furnace body
21	Retaining member
22	Char filled layer
51	Char supply part
52	Layer-thickness acquisition part
81	Gasification furnace
100	Flow path
101	Upstream space
102	Downstream space
411	Ejection port

Claims

1. A gas reforming furnace for reforming a pyrolysis gas supplied from a gasification furnace, comprising:

a furnace body forming a flow path for the pyrolysis gas;
a filled layer retainer provided in said flow path and retaining a char filled layer filled with char;
a tar combustor that supplies an oxygen-containing gas to said pyrolysis gas in a space upstream of said char filled layer in said flow path to burn tar contained in said pyrolysis gas before said pyrolysis gas passes through said char filled layer; and
a steam ejector that ejects steam from an ejection port provided inside said char filled layer or in proximity to said char filled layer.

2. The gas reforming furnace according to claim 1, wherein
said filled layer retainer includes a retaining member that has a plurality of holes and retains said char filled layer from underside.

3. The gas reforming furnace according to claim 1 or 2, further comprising:

a char supply part that supplies char to said filled layer retainer;
a layer-thickness acquisition part that acquires a thickness of said char filled layer; and
a controller that controls an amount of char supplied by said char supply part, on the basis of said thickness.

4. The gas reforming furnace according to any one of claims 1 to 3, wherein
a length of said tar combustor from a supply position of said oxygen-containing gas to a surface of said char filled layer in a direction of flow of said pyrolysis gas is greater than the thickness of said char filled layer.

5. The gas reforming furnace according to any one of claims 1 to 4, wherein
a temperature in a space downstream of said char filled layer in said flow path is lower than a temperature in said char filled layer.

FIG. 1

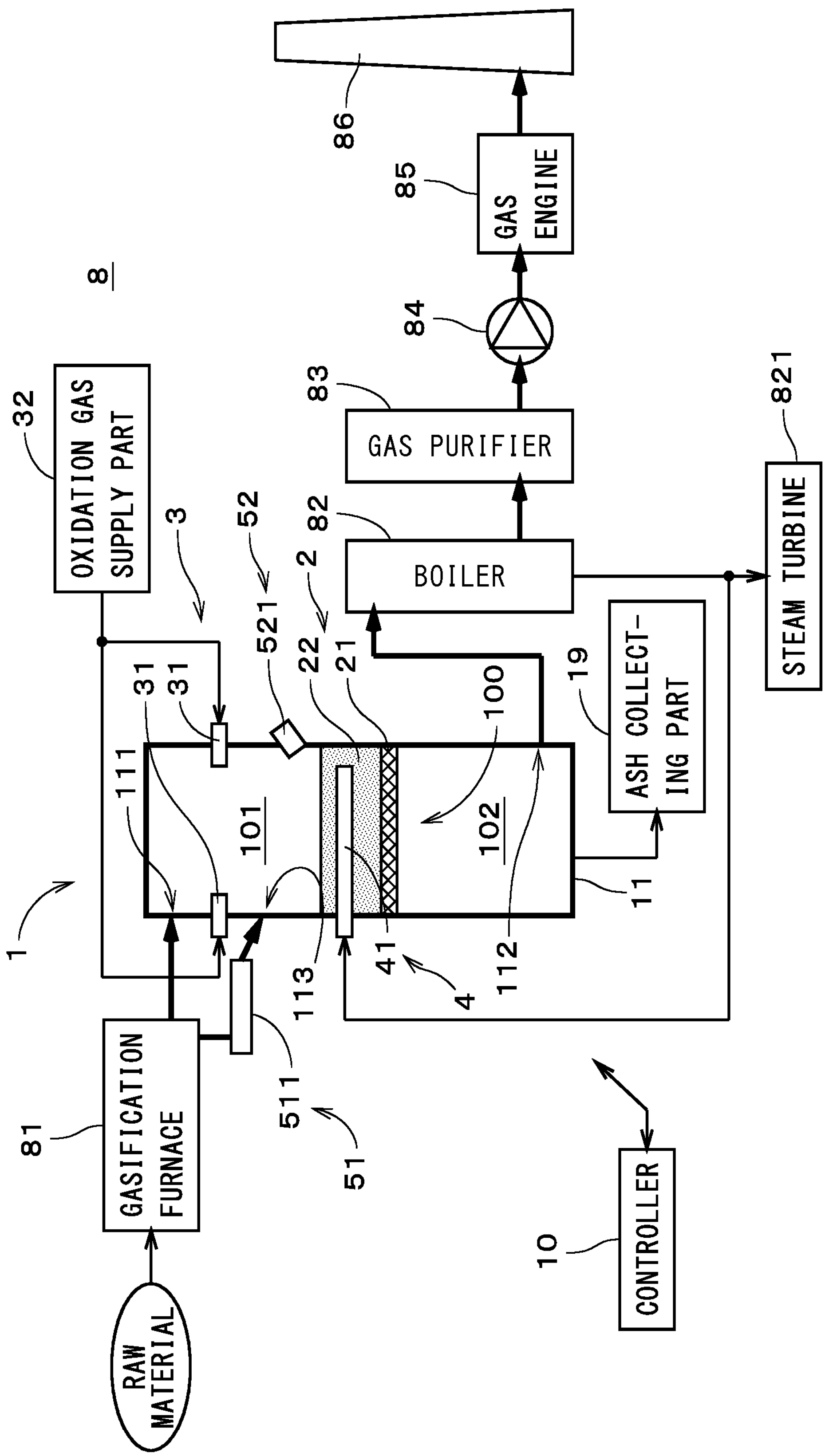

RAW MATERIAL
GASIFICATION FURNACE
81
OXIDATION GAS SUPPLY PART
32
8
1
3
31
31
111
101
113
52
521
511
51
2
22
21
41
4
100
102
112
11
19
ASH COLLECT-ING PART
BOILER
82
GAS PURIFIER
83
84
GAS ENGINE
85
86
STEAM TURBINE
821
CONTROLLER
10

FIG. 2

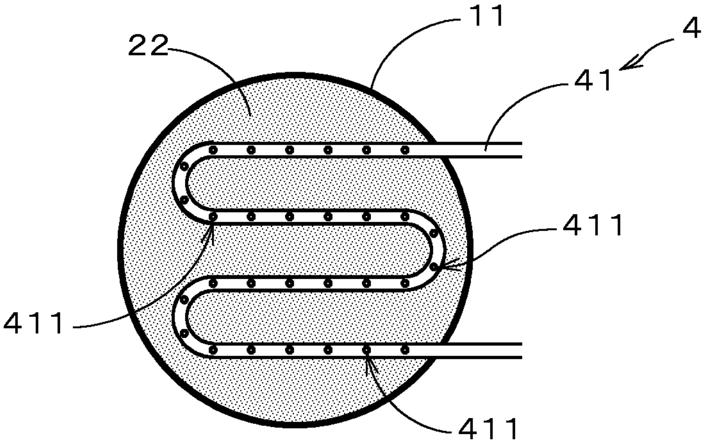


FIG. 3

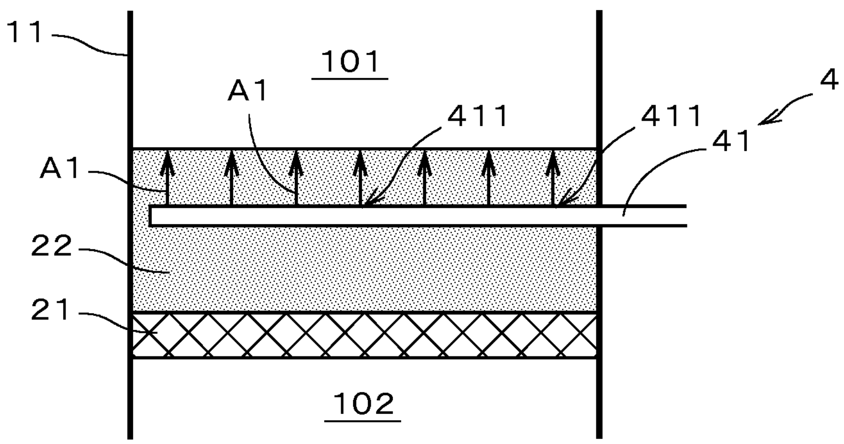


FIG. 4

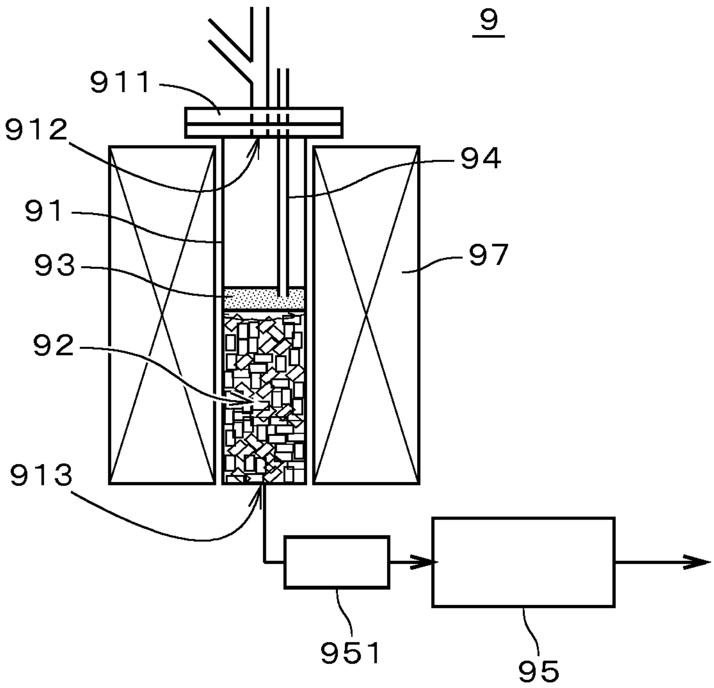

9
911
912
94
91
97
93
92
913
951
95

FIG. 5

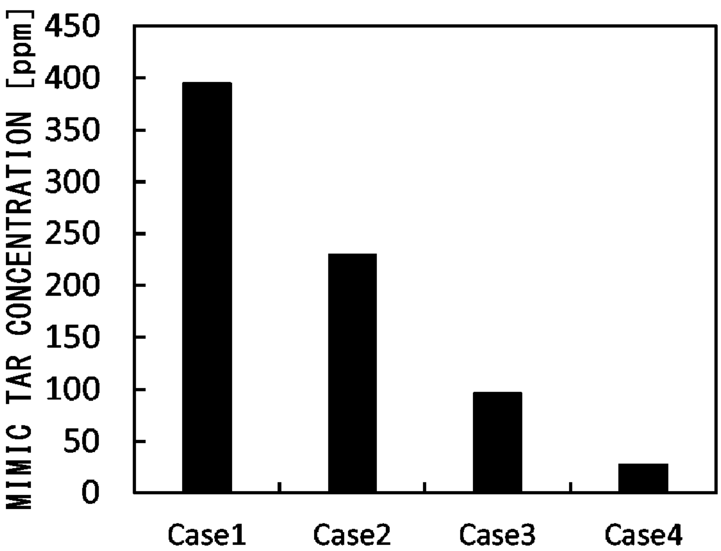

MIMIC TAR CONCENTRATION [ppm]
450
400
350
300
250
200
150
100
50
0
Case1
Case2
Case3
Case4

FIG. 6

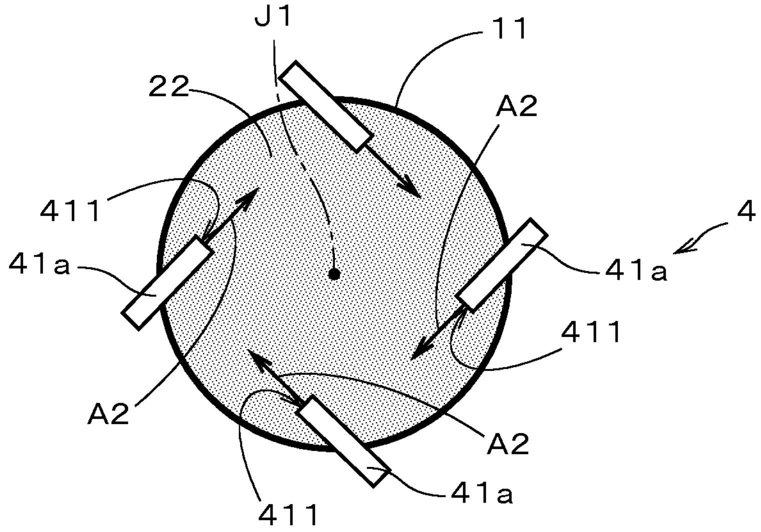


FIG. 7

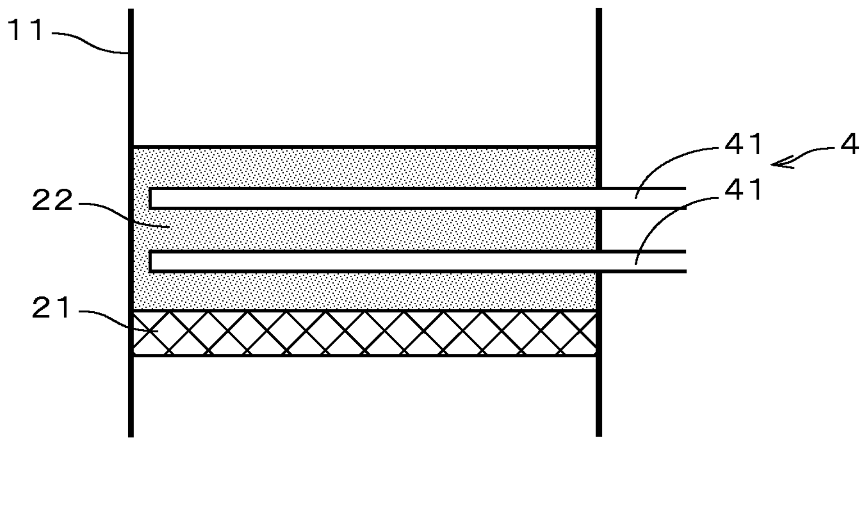
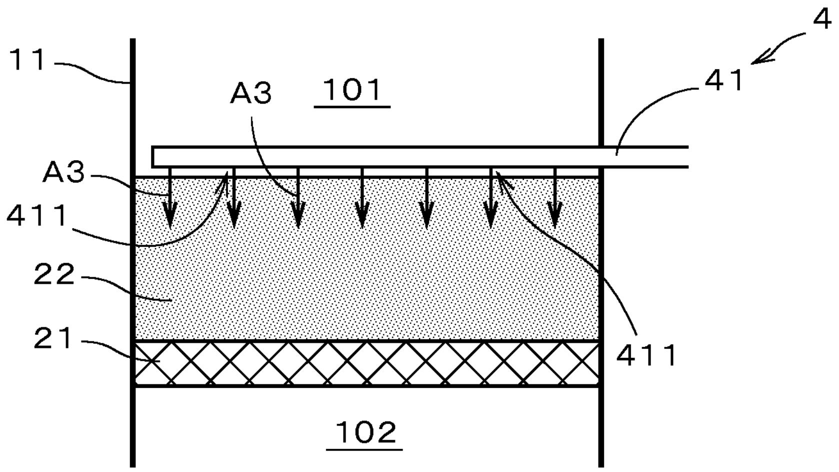


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2018/011753

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. C10K3/00(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)
Int.Cl. C10K3/00, C10J3/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2018
Registered utility model specifications of Japan	1996-2018
Published registered utility model applications of Japan	1994-2018

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2012-102181 A (MATSUSHITA, Yasuharu) 31 May 2012 & US 2014/0053465 A1 & WO 2012/063773 A1 & EP 2639288 A1 & CA 2817375 A & CN 103314081 A & KR 10-2013-0141573 A	1-5
A	JP 2009-57497 A (BIOCOKE LAB. CO., LTD.) 19 March 2009 (Family: none)	1-5
A	JP 2004-275901 A (KURIMOTO, LTD.) 07 October 2004 (Family: none)	1-5

☐ 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
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
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"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	Date of mailing of the international search report
12 April 2018 (12.04.2018)	24 April 2018 (24.04.2018)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2007177106 A **[0003]**
- JP 2007231063 A **[0004]**