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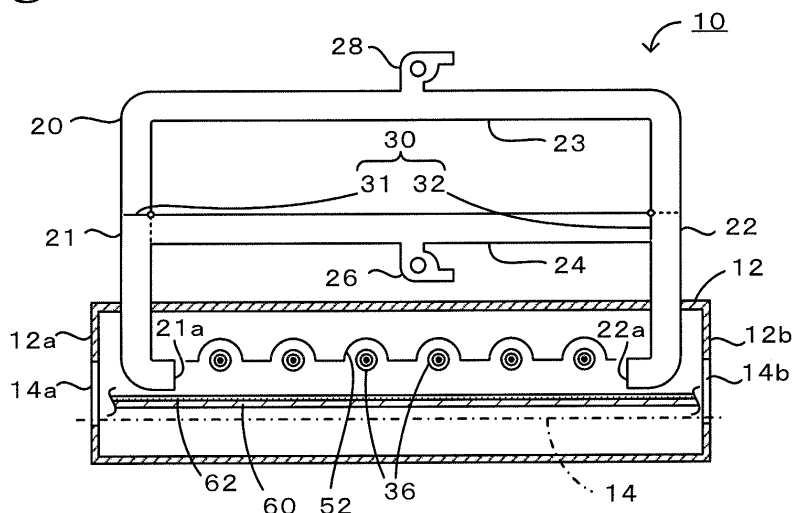
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(54) **DRYING FURNACE UNIT AND DRYING FURNACE**

(57) A drying oven unit 10 includes an oven body 12, a conveyance path 14, a pipe structure 20 having first and second vents 21a and 22a, a hot air generator 26, an exhaust blower 28, and an air-flow switching valve 30. The air-flow switching valve 30 includes first and second valves 31 and 32. Switching the first and second

valves 31 and 32 enables switching between permitting hot air generated by the hot air generator 26 to flow from the first vent 21a to the second vent 22a and permitting the hot air to flow from the second vent 22a to the first vent 21a.

Fig. 1



Description

Technical Field

[0001] The present invention relates to a drying oven unit and a drying oven.

Background Art

[0002] A drying oven for drying a sheet coated with slurry is known. For example, Patent Literature (PTL) 1 discloses a drying oven in which four drying zones having an entrance and an exit are coupled together in series along a predetermined direction. A top of each drying zone is provided with an air inlet and an air outlet. An air supply means for forcibly supplying air is attached to each air inlet. An exhaust means for forcibly exhausting air is attached to each air outlet. In this drying oven, the direction of air flow in each drying zone is the same as, and parallel to, a sheet conveying direction. PTL 1 explains that the direction of air flow may be made opposite the sheet conveying direction, but for efficient removal of evaporated organic solvent, it is preferable that the direction of air flow be the same as and parallel to the sheet conveying direction.

Citation List

Patent Literature

[0003] PTL 1: Japanese Unexamined Patent Application Publication No. 2008-302297

Summary of Invention

Technical Problem

[0004] PTL 1 neither describes nor suggests the technical idea of freely changing the air flow in each drying zone in the drying oven. Since the air supply means is attached to the air inlet and the exhaust means is attached to the air outlet, the direction of air flow is fixed to the direction from the air inlet to the air outlet. To reverse the air flow, the exhaust means is to be attached to the air inlet and the air supply means is to be attached to the air outlet. In this case, however, the direction of air flow is fixed to the direction from the air outlet to the air inlet. This means that the flow of air cannot be freely changed.

[0005] A primary object of the present invention is to provide a drying oven unit capable of freely changing the flow of air, and a drying oven including the drying oven unit.

Solution to Problem

[0006] A drying oven unit according to the present invention includes an oven body; a conveyance path passing through the oven body in a predetermined direction,

the conveyance path being a path along which a sheet coated with slurry on at least one side thereof is conveyed in the predetermined direction; first and second vents provided at respective ends of the conveyance path such that ambient gas flows along a slurry coated surface of the sheet; air supply means connected to the first vent and the second vent; and air-flow switching means for switching between permitting air from the air supply means to flow from the first vent to the second vent along the coated surface of the sheet and permitting air from the air supply means to flow from the second vent to the first vent along the coated surface of the sheet.

[0007] In the drying oven unit described above, by switching the air-flow switching means, air from the air supply means can be set to flow either from the first vent to the second vent along the coated surface of the sheet, or reversely from the second vent to the first vent along the coated surface of the sheet. In other words, the flow of ambient gas can be freely changed by switching the air-flow switching means.

[0008] The air supply means may supply either hot air (having, for example, a temperature of 60°C to 150°C) or cool air (having, for example, a room temperature or a temperature of 40°C to 50°C). The ambient gas is not limited to a specific one, but may be, for example, air or inert gas (such as nitrogen).

[0009] The drying oven unit according to the present invention preferably includes an infrared heater along the conveyance path, the infrared heater being disposed to face the coated surface of the sheet. Thus even when it is difficult to dry the slurry coated surface only by blowing air, the slurry coated surface can be dried in a short time by using the infrared heater along with blowing air. For example, the infrared heater to be used may be one in which the outer periphery of a filament is concentrically covered by a plurality of pipes functioning as filters that absorb infrared radiation having a wavelength of greater than 3.5 μm , and a flow path for a cooling fluid that suppresses an increase in surface temperature of the infrared heater is formed between the pipes (see Japanese Patent No. 4790092).

[0010] The drying oven unit according to the present invention preferably includes air-volume regulating means for regulating a volume of air from the air supply means. This makes it possible to freely change the volume of air as well as the direction of air flow.

[0011] In the drying oven unit according to the present invention, the sheet may be coated with slurry on both sides thereof, and the first and second vents may be provided for each of the slurry coated surfaces. Thus, both the slurry coated surfaces of the sheet can be dried simultaneously. This simultaneous drying requires less time than drying each surface at a time, and thus can enhance production efficiency.

[0012] A drying oven according to the present invention is formed by coupling together a plurality of drying oven units, each being the drying oven unit described above, such that conveyance paths are arranged in series along

the predetermined direction.

[0013] In the drying oven described above, the flow of ambient gas can be freely changed for each drying oven unit by switching the air-flow switching means in each drying oven unit. For example, the directions of air flows in adjacent drying oven units can be made the same or opposite. When the directions are made opposite, the air flows can either collide with, or move away from, each other.

[0014] In the drying oven according to the present invention, of the plurality of drying oven units, those at both ends of the drying oven may be set by the air-flow switching means such that the flows of air are directed from the outside to the inside. In this case, air is not easily blown out of either the conveyance path in the drying oven unit at one end of the drying oven or the conveyance path in the drying oven unit at the other end of the drying oven. Therefore, it is possible to maintain good environment in the room where the drying oven is installed.

[0015] The drying oven according to the present invention may include detecting means for detecting the amount of solvent evaporated from the slurry in each drying oven unit; and control means for controlling the air-flow switching means such that if the amount of solvent evaporated exceeds a predetermined value in successive drying oven units, flows of air in the successive drying oven units are directed in the same direction. When the amount of solvent evaporated in the successive drying oven units exceeds the predetermined value, if the flows of air in the successive drying oven units are directed in opposite directions, stagnation of ambient gas flow may occur in some area and evaporated solvent may accumulate in this area. However, since control is performed such that flows of air in the successive drying oven units are directed in the same direction, evaporated solvent is less likely to accumulate in any area.

Brief Description of Drawings

[0016]

Fig. 1 is a vertical cross-sectional view of a drying oven unit 10.

Fig. 2 is a vertical cross-sectional view of an infrared heater 36.

Fig. 3 is a cross-sectional view taken along line A-A of Fig. 2.

Fig. 4 illustrates switching of air flow in the drying oven unit 10; Fig. 4(a) illustrates the drying oven unit 10 in which hot air flows from a first vent 21a to a second vent 22a, and Fig. 4(b) illustrates the drying oven unit 10 in which hot air flows from the second vent 22a to the first vent 21a.

Fig. 5 illustrates a drying oven 70.

Fig. 6 illustrates a relationship between an evaporation curve and an air flow direction in each of drying oven units U1 to U7 included in the drying oven 70. Fig. 7 is a vertical cross-sectional view of a drying

oven unit 110.

Fig. 8 illustrates a drying oven 170.

Fig. 9 illustrates a modification of the drying oven 70.

5 Description of Embodiments

[0017] A preferred embodiment of the present invention will now be described with reference to the drawings. Fig. 1 is a vertical cross-sectional view of a drying oven unit 10. Fig. 2 is a vertical cross-sectional view of an infrared heater 36. Fig. 3 is a cross-sectional view taken along line A-A of Fig. 2.

[0018] The drying oven unit 10 includes an oven body 12, a conveyance path 14, a pipe structure 20 having first and second vents 21a and 22a, a hot air generator 26, an exhaust blower 28, an air-flow switching valve 30, and infrared heaters 36.

[0019] The oven body 12 is a heat insulating structure substantially in the shape of a substantially rectangular parallelepiped. The oven body 12 has a front end face 12a and a rear end face 12b provided with an opening 14a and an opening 14b, respectively. A distance between the front end face 12a and the rear end face 12b of the oven body 12 is 2 m to 6 m.

[0020] A conveyance path 14 is a path extending from the opening 14a to the opening 14b. The conveyance path 14 horizontally passes through the oven body 12. A sheet 60 coated with slurry on one side thereof passes along the conveyance path 14. Specifically, with a surface coated with slurry (slurry coated surface) 62 facing up, the sheet 60 is introduced through the opening 14a into the oven body 12, horizontally conveyed in the oven body 12, and discharged through the opening 14b.

[0021] The pipe structure 20 has a first pipe segment 21 vertically passing through a ceiling of the oven body 12 at a location near the front end face 12a, a second pipe segment 22 vertically passing through the ceiling of the oven body 12 at a location near the rear end face 12b, a third pipe segment 23 connecting an upper end of the first pipe segment 21 to an upper end of the second pipe segment 22, and a fourth pipe segment 24 connecting a midpoint of the first pipe segment 21 to a midpoint of the second pipe segment 22. That is, the third pipe segment 23 and the fourth pipe segment 24 are paths that connect the first pipe segment 21 in parallel with the second pipe segment 22. The first pipe segment 21 is bent inside the oven body 12 to allow a lower end portion thereof to face in the horizontal direction. Therefore, the first vent 21a, which is an opening at the lower end of the first pipe segment 21, is open toward the rear end face 12b. The second pipe segment 22 is bent inside the oven body to allow a lower end portion thereof to face in the horizontal direction. Therefore, the second vent 22a, which is an opening at the lower end of the second pipe segment 22, is open toward the front end face 12a. The first vent 21a and the second vent 22a are positioned to face each other. The first vent 21a and the second vent 22a may be located at different heights, but are often

located at the same height. Therefore, the flow of air from one of the first and second vents 21a and 22a into the other is directed along the slurry coated surface 62 of the sheet 60.

[0022] The hot air generator 26 is attached to the fourth pipe segment 24. The hot air generator 26 is configured to supply hot air to the inside of the fourth pipe segment 24. The hot air generator 26 is capable of regulating the air volume.

[0023] The exhaust blower 28 is attached to the third pipe segment 23. The exhaust blower 28 has the function of discharging gas in the third pipe segment 23 to the outside. The exhaust blower 28 is also capable of regulating the air volume.

[0024] The air-flow switching valve 30 includes a first valve 31 at a joint between the first pipe segment 21 and the fourth pipe segment 24, and a second valve 32 at a joint between the second pipe segment 22 and the fourth pipe segment 24. The first valve 31 is switched between a position (indicated by a solid line in Fig. 1 and referred to as an air supply position) for both permitting communication between the first pipe segment 21 and the fourth pipe segment 24 and blocking communication between the first pipe segment 21 and the third pipe segment 23 and a position (indicated by a dotted line in Fig. 1 and referred to as an exhaust position) for both blocking communication between the first pipe segment 21 and the fourth pipe segment 24 and permitting communication between the first pipe segment 21 and the third pipe segment 23. The second valve 32 is switched between a position (indicated by a solid line in Fig. 1 and referred to as an exhaust position) for both blocking communication between the second pipe segment 22 and the fourth pipe segment 24 and permitting communication between the second pipe segment 22 and the third pipe segment 23 and a position (indicated by a dotted line in Fig. 1 and referred to as an air supply position) for both permitting communication between the second pipe segment 22 and the fourth pipe segment 24 and blocking communication between the second pipe segment 22 and the third pipe segment 23. Each of the valves 31 and 32 may be switched either manually or electrically by an electromagnetic solenoid. Although not shown, a piping system for circulation may be added between pipes to compensate for part of supply air with part of exhaust air.

[0025] A plurality of infrared heaters 36 are mounted near the ceiling of the oven body 12. Each of the infrared heaters 36 is mounted such that the longitudinal direction thereof is orthogonal to the conveyance direction. As illustrated in Figs. 2 and 3, each infrared heater 36 includes a heater main body 42 formed by surrounding a filament 38 with an inner pipe 40, an outer pipe 44 surrounding the heater main body 42, caps 46 each having a cylindrical shape with a bottom and airtightly fitted over the corresponding end of the outer pipe 44, and a flow path 48 formed between the heater main body 42 and the outer pipe 44 and permitting circulation of a cooling fluid. The filament 38 is electrically heated to a temperature of

700°C to 1200°C, and emits infrared radiation with a peak wavelength of around 3 μm . An electric wire 38a connected to the filament 38 extends through a wire lead portion 46a of each cap 46 and is airtightly led to the outside. The inner pipe 40 is made of silica glass, borosilicate crown glass, or the like. The inner pipe 40 functions as a filter that transmits infrared radiation having a wavelength of 3.5 μm or less and absorbs infrared radiation having a wavelength of greater than 3.5 μm . The heater main body 42 is supported by holders 50 disposed inside the respective caps 46 at both ends thereof. Like the inner pipe 40, the outer pipe 44 is made of silica glass, borosilicate crown glass, or the like. The outer pipe 44 functions as a filter that transmits infrared radiation having a wavelength of 3.5 μm or less and absorbs infrared radiation having a wavelength of greater than 3.5 μm . Each cap 46 has a fluid port 46b. The flow path 48 allows a cooling fluid to flow from one fluid port 46b to the other fluid port 46b. Examples of the cooling fluid flowing through the flow path 48 include air and inert gas. The cooling fluid cools the inner pipe 40 and the outer pipe 44 by contacting them to remove heat therefrom. When infrared radiation having a peak wavelength of around 3 μm is emitted from the filament 38 of the infrared heater 36, infrared radiation having a wavelength of 3.5 μm or less passes through the inner pipe 40 and the outer pipe 44 and is applied to the slurry coated surface 62 of the sheet 60 passing along the conveyance path. Infrared radiation having a wavelength of 3.5 μm or less is said to be highly capable of breaking hydrogen bonding in an organic solvent contained in the slurry coated surface 62 of the sheet 60, and can efficiently evaporate the organic solvent. The inner pipe 40 and the outer pipe 44 absorb infrared radiation having a wavelength of greater than 3.5 μm , but are cooled by the cooling fluid flowing through the flow path 48. Therefore, the inner pipe 40 and the outer pipe 44 can be kept at a temperature below the ignition point of the organic solvent evaporated from the slurry coated surface 62.

[0026] The infrared heater 36 is disposed in an inner space of each arched groove 52 in a reflective plate near the ceiling of the oven body 12. Like the infrared heater 36, the arched groove 52 extends in a direction orthogonal to the conveyance direction. The cross section of the arched groove 52 has a curved shape, such as a parabolic shape, an elliptical arc shape, or a circular arc shape. The infrared heater 36 is disposed at a focal or central point of the cross section of the arched groove 52. Thus, the infrared radiation having a wavelength of 3.5 μm or less emitted from the infrared heater 36 is reflected by the arched groove 52 and efficiently applied to the slurry coated surface 62.

[0027] Switching of air flow in the drying oven unit 10 will now be described. Fig. 4 illustrates switching of air flow in the drying oven unit 10. Fig. 4(a) illustrates the drying oven unit 10 in which hot air flows from the first vent 21a to the second vent 22a, and Fig. 4(b) illustrates the drying oven unit 10 in which hot air flows from the

second vent 22a to the first vent 21a.

[0028] To permit hot air to flow from the first vent 21a to the second vent 22a, the first valve 31 is set to the air supply position and the second valve 32 is set to the exhaust position as illustrated in Fig. 4(a). Specifically, the first valve 31 is set to the position for both permitting communication between the first pipe segment 21 and the fourth pipe segment 24 and blocking communication between the first pipe segment 21 and the third pipe segment 23. At the same time, the second valve 32 is set to the position for both blocking communication between the second pipe segment 22 and the fourth pipe segment 24 and permitting communication between the second pipe segment 22 and the third pipe segment 23. Thus, hot air supplied from the hot air generator 26 to the fourth pipe segment 24 passes through the first pipe segment 21 and is blown out of the first vent 21a. Gas passing through the second vent 22a and the second pipe segment 22 is discharged from the third pipe segment 23 by the exhaust blower 28. Thus, in the oven body 12, hot air flows from the first vent 21a to the second vent 22a.

[0029] To permit hot air to flow from the second vent 22a to the first vent 21a, the second valve 32 is set to the air supply position and the first valve 31 is set to the exhaust position as illustrated in Fig. 4(b). Specifically, the second valve 32 is set to the position for both permitting communication between the second pipe segment 22 and the fourth pipe segment 24 and blocking communication between the second pipe segment 22 and the third pipe segment 23. At the same time, the first valve 31 is set to the position for both blocking communication between the first pipe segment 21 and the fourth pipe segment 24 and permitting communication between the first pipe segment 21 and the third pipe segment 23. Thus, hot air supplied from the hot air generator 26 to the fourth pipe segment 24 passes through the second pipe segment 22 and is blown out of the second vent 22a. Gas passing through the first vent 21a and the first pipe segment 21 is discharged from the third pipe segment 23 by the exhaust blower 28. Thus, in the oven body 12, hot air flows from the second vent 22a to the first vent 21a.

[0030] Next, a drying oven 70 will be described, which is formed by coupling together a plurality of drying oven units 10 such that a plurality of conveyance paths 14 are arranged in a straight line along the horizontal direction. Fig. 5 illustrates the drying oven 70. Fig. 6 illustrates a relationship between an evaporation curve and an air flow direction in each of the drying oven units 10 included in the drying oven 70.

[0031] As illustrated in Fig. 5, the drying oven 70 is formed by coupling the front end face 12a of each drying oven unit 10, with bolts, to the rear end face 12b of the adjacent drying oven unit 10. A gasket (not shown) ensures airtightness of the opening 14a of the front end face 12a and the opening 14b of the rear end face 12b. The gasket may be made of any material resistant to an organic solvent. For example, the gasket may be made

of polytetrafluoroethylene. When the gasket 18 provides good sealing, the bolt coupling may not be necessary. Although the drying oven 70 is installed in a drying oven installation room, the exhaust blowers 28 may be installed outside the drying oven installation room. Even when the exhaust blowers 28 are installed indoors, since each blower outlet is connected through a duct to an air outlet leading to the outside of the building, air discharged from the exhaust blower 28 is not released into the drying oven installation room.

[0032] Assume that seven drying oven units 10 are coupled together to form the drying oven 70 as illustrated in Fig. 6. For convenience, the drying oven units 10 are referred to as a drying oven unit U1, a drying oven unit U2, ..., and a drying oven unit U7, from the left in this order. The sheet 60 is unwound from a roll 72 at the left end of the drying oven 70, coated with slurry on the upper surface thereof by a coater (not shown) immediately before being introduced into the drying oven 70, and introduced through the opening 14a of the drying oven unit U1 into the drying oven 70. As the sheet 60 passes through the drying oven units U1 to U7, the organic solvent is evaporated from the slurry coated surface 62, and the evaporated organic solvent is discharged to the outside by the exhaust blower 28. The sheet 60 is eventually taken out through the opening 14b of the drying oven unit U7 and wound on a roll 74 at the right end of the drying oven 70. The organic solvent is evaporated from the slurry coated surface 62 by the action of infrared radiation from the infrared heaters 36 and hot air from the hot air generators 26.

[0033] Assume that a numerical simulation is performed in advance for the case where the sheet 60 having the slurry coated surface 62 is dried by the drying oven 70, and that the resulting evaporation curve has a profile shown in Fig. 6. The evaporation curve shows that immediately after the sheet 60 is introduced into the drying oven unit U1, the amount of evaporation of the organic solvent is small because the sheet temperature is not sufficiently high. The amount of evaporation is very large in the drying oven units U2 to U4. Then in the drying oven unit U5 and the subsequent units, that is, after evaporation of most of the organic solvent, the amount of evaporation is small. In the drying oven units U2 to U4 where the evaporation curve exceeds a threshold (indicated by a dotted line) of the amount of evaporation, the solvent may accumulate unless all flows of hot air are directed in the same direction. That is, if the direction of hot air flow in any of the drying oven units U2 to U4 is different from that in the other units, stagnation of air flow occurs in an area where the directions of hot air flows are different (for example, where flows of hot air collide with, or move away from, each other) and the evaporated solvent may accumulate in that area. However, since all the flows of hot air in these drying oven units are directed in the same direction here, the evaporated solvent is less likely to accumulate in any area. In normal design work, a plan is made in which, after each unit is individually designed,

the amount of hot air required to dilute a volatile solvent within the designed unit is secured. Even when this is used as a design basis, it is preferable to enhance safety by using a mechanism in which air is supplied to and discharged from each unit in a coordinated manner in an area where a large amount of solvent is evaporated.

[0034] In each of the drying oven units U1 and U7 at respective ends of the drying oven 70, the flow of hot air is directed from the outside to the inside. Therefore, the hot air is not easily blown out of either the opening 14a of the drying oven unit U1 or the opening 14b of the drying oven unit U7. In this case, since the directions of air flows in the drying oven units U1 and U7 are opposite, the drying oven 70 has at least one connection point at which air flows are opposed to each other. It is preferable that the connection point be set to a position where the amount of solvent evaporation is small. However, since the shape of the evaporation curve varies depending on the type of slurry coated, it is necessary to move the connection point to an appropriate position in accordance with the type of the slurry. Such a manipulation is possible in the present invention, because the direction of air flow can be changed for each drying oven unit.

[0035] The sheet 60 having the slurry coated surface 62 is not limited to a specific type. For example, a sheet coated with electrodes for a lithium-ion secondary battery may be used. Examples of such a sheet include a metal sheet, such as an aluminum or copper sheet, coated with electrode slurry made by blending a positive-electrode active material (or negative-electrode active material) with a binder, a conductive material, and an organic solvent. Alternatively, a fired ceramic sheet coated with an unfired ceramic compact may be used. Examples of such a sheet include a fired ceramic sheet coated with slurry made by blending ceramic particles with a binder and water (or organic solvent).

[0036] In the drying oven unit 10 of the present embodiment described above, by switching the air-flow switching valve 30, hot air can be set to flow either from the first vent 21a to the second vent 22a along the slurry coated surface 62 of the sheet 60, or reversely from the second vent 22a to the first vent 21a along the slurry coated surface 62 of the sheet 60. In other words, the flow of air can be freely changed by switching the air-flow switching valve 30.

[0037] Also, since the infrared heaters 36 are provided, even when it is difficult to dry the slurry coated surface 62 with hot air alone, the slurry coated surface 62 can be dried in a short time by using the infrared heaters 36 along with hot air. The infrared heaters 36 emit infrared radiation having a wavelength of 3.5 μm or less and keep the heater surface temperature as low as below the ignition point of the organic solvent. Therefore, it is possible not only to efficiently evaporate the organic solvent, but also prevent the organic solvent from being ignited.

[0038] Additionally, since the hot air generator 26 and the exhaust blower 28 are capable of regulating the air volume, it is possible to freely change the volume as well

as the direction of hot air.

[0039] As described above, the drying oven 70 is formed by coupling the drying oven units U1 to U7 together such that the conveyance paths are arranged in series along the conveyance direction of the sheet 60. Therefore, by switching the air-flow switching valve 30 in each of the drying oven units U1 to U7, the flow of air can be freely changed for each of the drying oven units U1 to U7. For example, the directions of hot air flows in adjacent drying oven units can be made the same or opposite. When the directions are made opposite, the flows of hot air can either collide with, or move away from, each other. To prevent solvent accumulation, the flow of hot air in each of the drying oven units U1 to U7 can be regulated in accordance with the evaporation curve.

[0040] As described above, each of the drying oven units U1 and U7 at the respective ends of the drying oven 70 is set such that the flow of hot air is directed from the outside to the inside. Therefore, the hot air is not easily blown out of either the conveyance path 14 in the drying oven unit U1 or the conveyance path 14 in the drying oven unit U7. It is thus possible to maintain good environment in the drying oven installation room where the drying oven 70 is installed.

[0041] The present invention is by no means limited to the embodiments described above, and can be carried out in various modes within the technical scope of the present invention.

[0042] In the embodiments described above, the drying oven unit 10 and the drying oven 70 are designed to dry the sheet 60 coated with slurry on one side thereof. Alternatively, as illustrated in Figs. 7 and 8, a drying oven unit 110 and a drying oven 170 may be designed to dry a sheet 160 coated with slurry on both sides thereof. In the drying oven unit 110 and the drying oven 170, the same components as those of the drying oven unit 10 and the drying oven 70 described above are given the same reference numerals and their description will be omitted. The drying oven unit 110 illustrated in Fig. 7 is used to dry the sheet 160 having slurry coated surfaces 162 on both sides. The drying oven unit 110 includes the pipe structure 20 having the first and second vents 21a and 22a, the hot air generator 26, the exhaust blower 28, the air-flow switching valve 30, and the infrared heaters 36 for each of the slurry coated surfaces 162. As in the embodiments described above, the direction of air flow can be switched by means of the first and second valves 31 and 32 of the air-flow switching valve 30.

[0043] The drying oven 170 illustrated in Fig. 8 is formed by coupling a plurality of drying oven units 110 together such that the conveyance paths 14 are arranged in a straight line along the horizontal direction. The drying oven units 110 are coupled together in the same manner as in the drying oven 70. Again, for convenience, the drying oven units 110 are referred to as a drying oven unit U1, a drying oven unit U2, ..., and a drying oven unit U7, from the left in this order. The sheet 160 is unwound from the roll 72 at the left end of the drying oven 170,

coated with slurry on both the upper and lower surfaces thereof by a rotor (not shown) immediately before being introduced into the drying oven 70, and introduced through the opening 14a of the drying oven unit U1 into the drying oven 70. As the sheet 160 passes through the drying oven units U1 to U7, the organic solvent is evaporated from the upper and lower slurry coated surfaces 162 and the evaporated organic solvent is discharged by each exhaust blower 28 to the outside. The sheet 160 is eventually taken out through the opening 14b of the drying oven unit U7 and wound on the roll 74 at the right end of the drying oven 170. As in the drying oven 70 described above, the direction of hot air flow in each of the drying oven units U1 to U7 is determined on the basis of an evaporation curve obtained by a numerical simulation. In the drying oven units U1 and U7 at the respective ends of the drying oven 170, the flow of hot air is directed from the outside to the inside. Therefore, the hot air is not easily blown out of either the opening 14a of the drying oven unit U1 or the opening 14b of the drying oven unit U7. The drying oven units 110 and the drying oven 170 can simultaneously dry both the slurry coated surfaces of the sheet 160. This simultaneous drying requires less time than drying each surface at a time, and thus can enhance production efficiency.

[0044] In the embodiments described above, the direction of hot air flow in each of the drying oven units U1 to U7 is determined on the basis of the evaporation curve. Alternatively, the direction of hot air flow may be changed while the sheet 60 is being dried. In this case, the direction of air flow may be changed either manually or automatically. An example of automatically changing the direction of air flow will be described with reference to Fig. 9. A sensor S for detecting the amount of solvent evaporated from the slurry coated surface 62 is attached to each drying oven unit 10 of the drying oven 70. Solenoid valves are used as the first and second valves 31 and 32. Additionally, a controller C is prepared. Each sensor S is connected to the corresponding input port of the controller C, and the first and second valves 31 and 32 are connected to the corresponding output ports of the controller C. Thus, a signal related to the amount of solvent evaporation output from each sensor S is input to the controller C. From the controller C, a driving signal is output to the first and second valves 31 and 32. Then, for a plurality of successive drying oven units, the controller C determines whether the amount of solvent evaporation exceeds a predetermined threshold. If the threshold is exceeded, the controller C controls the first and second valves 31 and 32 such that the flows of hot air in the successive drying oven units are directed in the same direction. When the amount of solvent evaporation in the successive drying oven units exceeds the threshold, if the flows of hot air in these drying oven units are directed in opposite directions, stagnation of air flow may occur in some area and evaporated solvent may accumulate in this area. However, since control is performed such that flows of air in the drying oven units are directed in

the same direction, evaporated solvent is less likely to accumulate in any area. The type of the sensor S may be selected depending on the type of the organic solvent used in the slurry. For example, a hydrocarbon (HC) sensor may be selected for a hydrocarbon solvent, and an alcohol sensor may be selected for an alcohol solvent.

[0045] In the embodiments described above, each conveyance path 14 may be provided with some supporting rollers that support the sheet 60 from below. This can prevent the sheet 60 from being bent by gravity. However, when the sheet 160 has the slurry coated surfaces 162 on both sides as illustrated in Figs. 7 and 8, it is preferable not to provide any supporting rollers. This is because the slurry coated surfaces 62 may come into contact with such supporting rollers, and unintended surface irregularities may be produced.

[0046] The infrared heaters 36 are mounted in the ceiling of the oven body 12 in the embodiments described above. The infrared heaters 36 may not be provided if the slurry coated surface 62 of the sheet 60 is thin enough to be sufficiently dried with hot air alone.

[0047] Each infrared heater 36 used in the embodiments described above is one in which the outer periphery of the filament 38 is concentrically covered by a plurality of pipes 40 and 44 functioning as filters that absorb infrared radiation having a wavelength of greater than 3.5 μm , and the flow path 48 for a cooling fluid that suppresses an increase in surface temperature of the infrared heater 36 is formed between the pipes 40 and 44. However, other types of infrared heaters may be used.

[0048] Although the drying oven 70 is formed by a plurality of drying oven units 10 arranged in series in the embodiments described above, a drying oven formed by a single drying oven unit 10 may be used.

[0049] Although air is used as an ambient gas in each drying oven unit 10 in the embodiments described above, an inert gas, such as nitrogen, may be used instead of air.

[0050] Although the hot air generator 26 is used as air supply means in the embodiments described above, the air supply means is not particularly limited to this. For example, a cool air generator that generates cool air having a temperature of 40°C to 50°C may be used as the air supply means.

[0051] The present application claims priority from Japanese Patent Application No. 2012-10631 filed on January 23, 2012, the entire contents of which are incorporated herein by reference.

Industrial Applicability

[0052] The present invention is applicable in industries that involve drying sheets coated with slurry. Examples of the industries include battery industries that manufacture electrode coatings for lithium-ion secondary batteries, ceramic industries that manufacture ceramic layered products formed by two-layer ceramic sintered bodies, and film manufacturing industries that manufacture optical film products.

Reference Signs List

[0053] 10 drying oven unit, 12 oven body, 12a front end face, 12b rear end face, 14 conveyance path, 14a opening, 14b opening, 20 pipe structure, 21 first pipe segment, 21a first vent, 22 second pipe segment, 22a second vent, 23 third pipe segment, 24 fourth pipe segment, 26 hot air generator, 28 exhaust blower, 30 air-flow switching valve, 31 first valve, 32 second valve, 36 infrared heater, 38 filament, 38a electric wire, 40 inner pipe, 42 heater main body, 44 outer pipe, 46 cap, 46a wire lead portion, 46b fluid port, 48 flow path, 50 holder, 52 arched groove, 60 sheet, 62 slurry coated surface, 70 drying oven, 72 roll, 74 roll, 110 drying oven unit, 160 sheet, 162 slurry coated surface, 170 drying oven, C controller, S sensor, U1-U7 drying oven unit

Claims

1. A drying oven unit comprising:

an oven body,
 a conveyance path passing through the oven body in a predetermined direction, the conveyance path being a path along which a sheet coated with slurry on at least one side thereof is conveyed in the predetermined direction, first and second vents provided at respective ends of the conveyance path such that ambient gas flows along a slurry coated surface of the sheet,
 air supply means connected to the first vent and the second vent, and
 air-flow switching means for switching between permitting air from the air supply means to flow from the first vent to the second vent along the coated surface of the sheet and permitting air from the air supply means to flow from the second vent to the first vent along the coated surface of the sheet.

2. The drying oven unit according to Claim 1, comprising an infrared heater along the conveyance path, the infrared heater being disposed to face the coated surface of the sheet.

3. The drying oven unit according to Claim 1 or 2, comprising air-volume regulating means for regulating a volume of air from the air supply means.

4. The drying oven unit according to any one of Claims 1 to 3, wherein the sheet is coated with slurry on both sides thereof, and the first and second vents are provided for each of the slurry coated surfaces.

5. A drying oven formed by coupling together a plurality of drying oven units, each being the drying oven unit according to any one of Claims 1 to 4, such that conveyance paths are arranged in series along the predetermined direction.

6. The drying oven according to Claim 5, wherein the plurality of drying oven units, those at both ends of the drying oven are set by the air-flow switching means such that the flows of air are directed from the outside to the inside.

7. The drying oven according to Claim 5 or 6, comprising:

detecting means for detecting the amount of solvent evaporated from the slurry in each drying oven unit, and
 control means for controlling the air-flow switching means such that if the amount of solvent evaporated exceeds a predetermined value in successive drying oven units, flows of air in the successive drying oven units are directed in the same direction.

Fig. 1

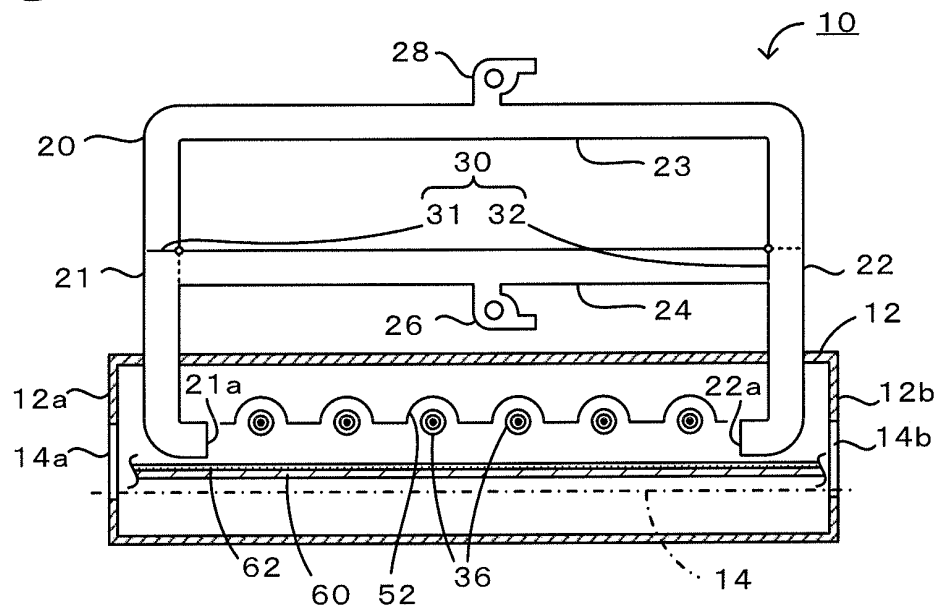


Fig. 2

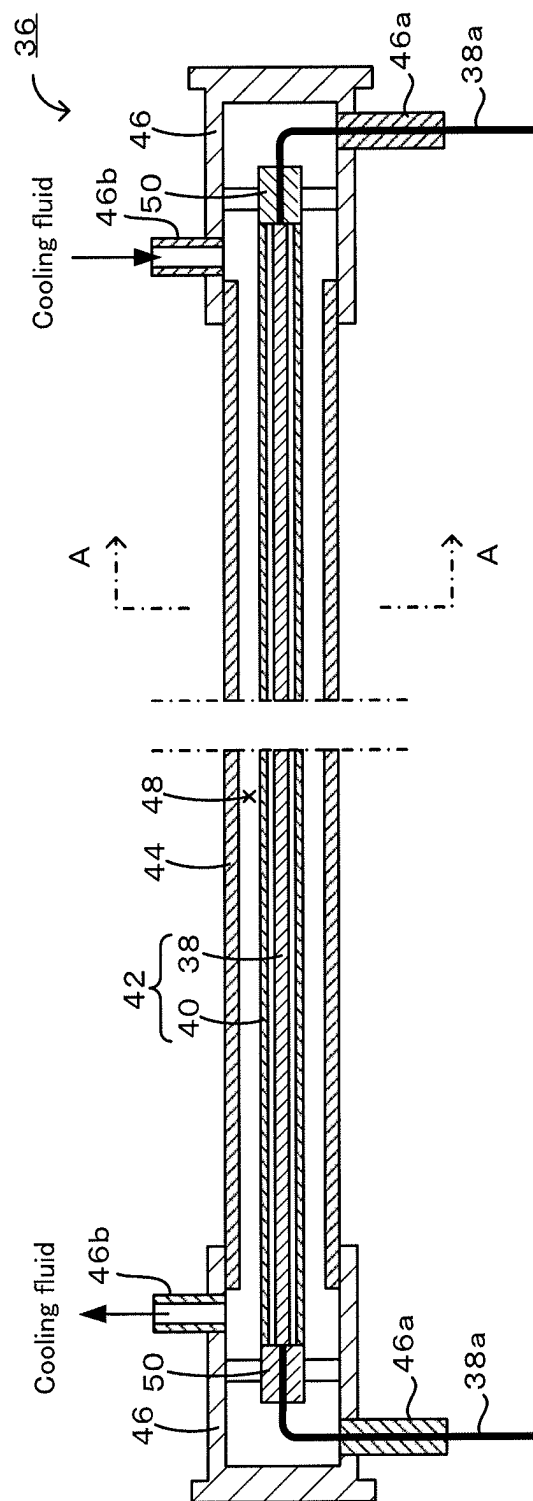


Fig. 3

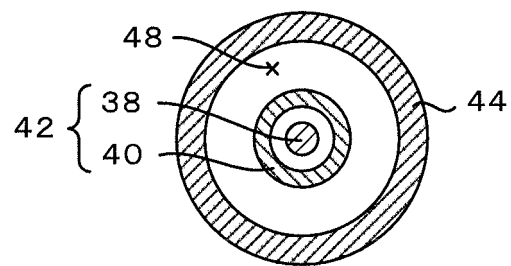
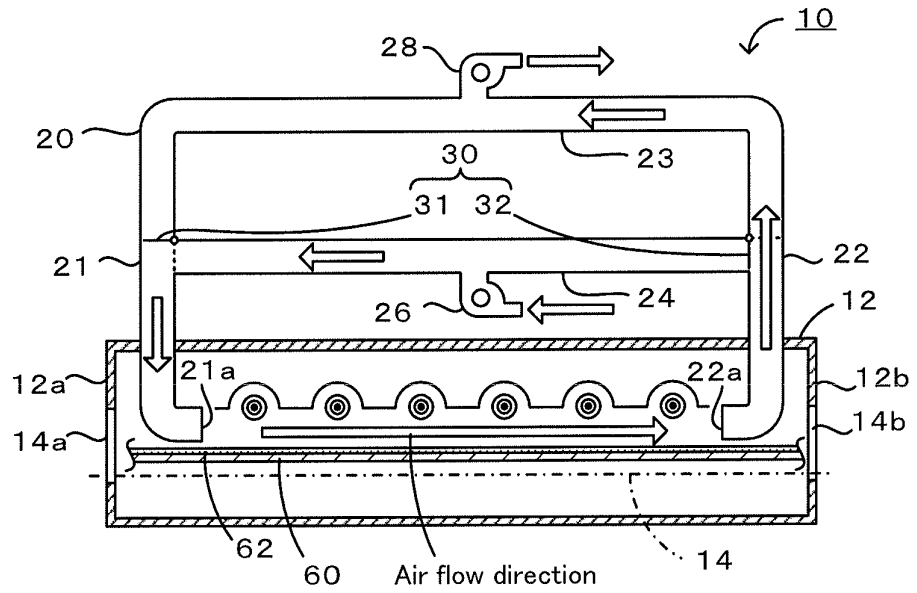


Fig. 4

(a)



(b)

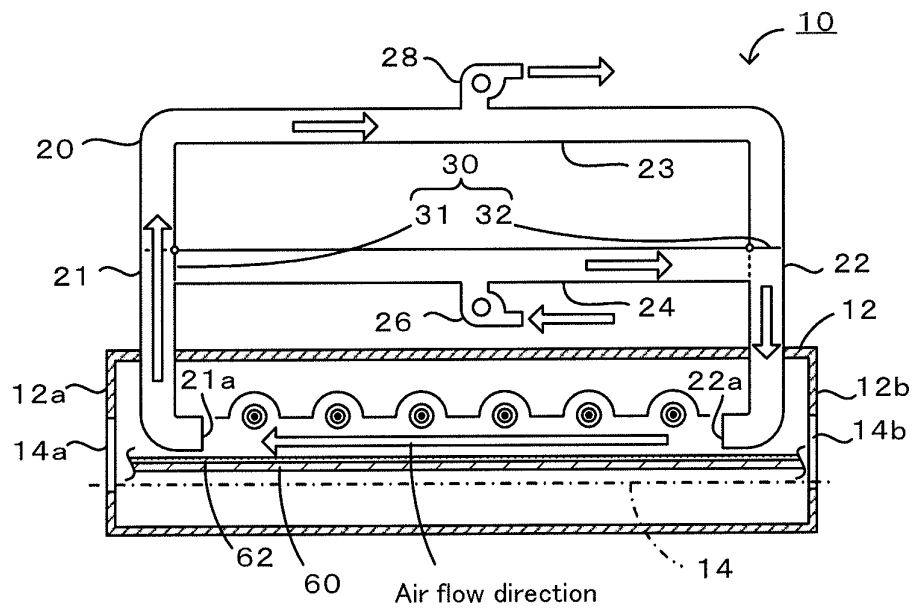


Fig. 5

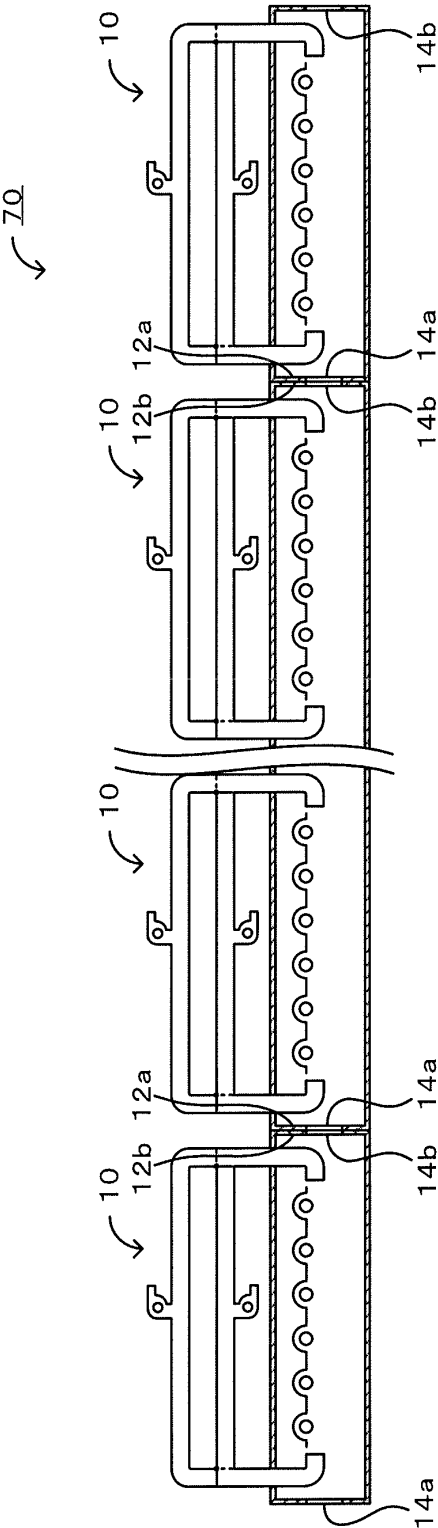


Fig. 6

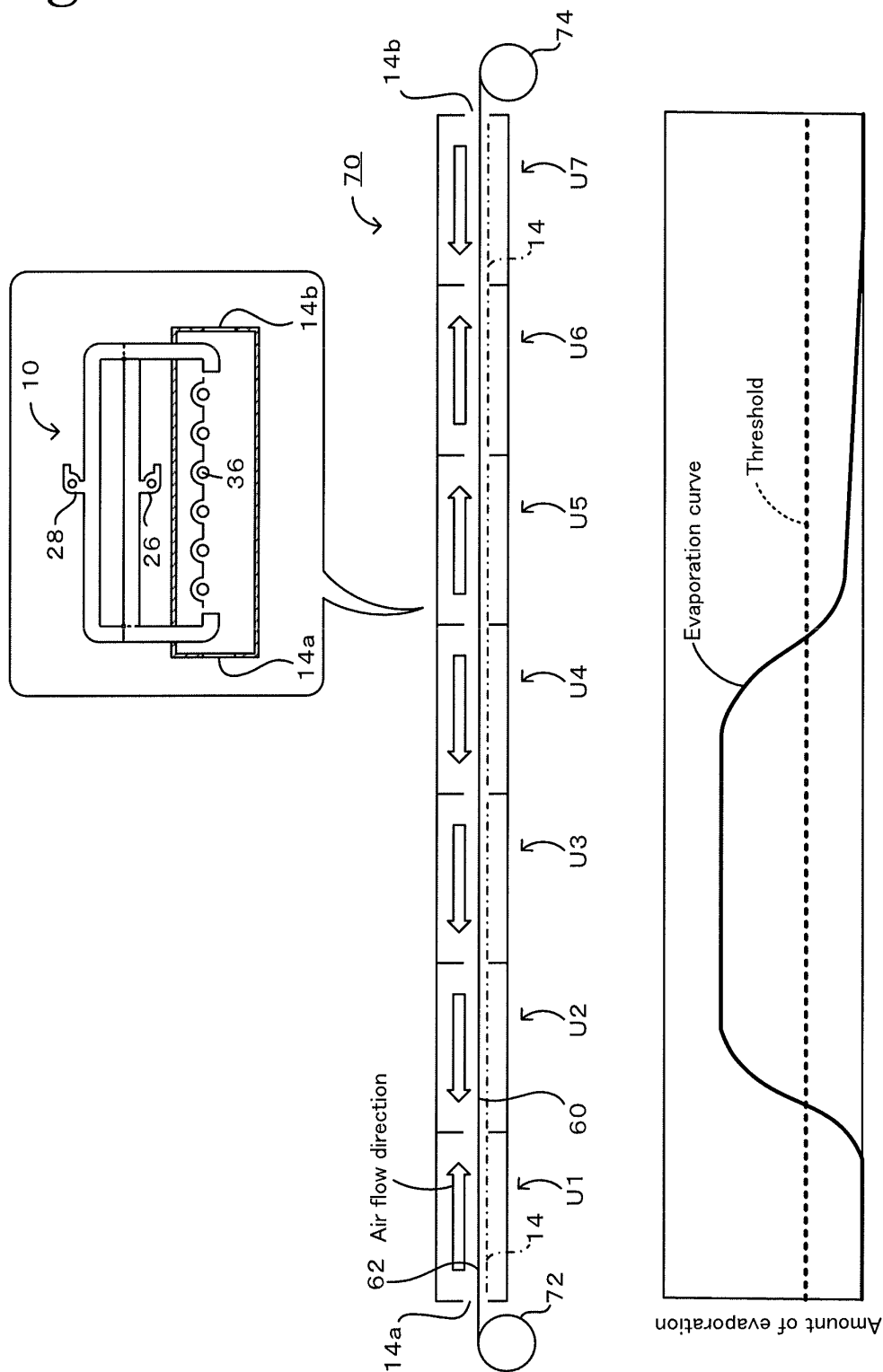


Fig. 7

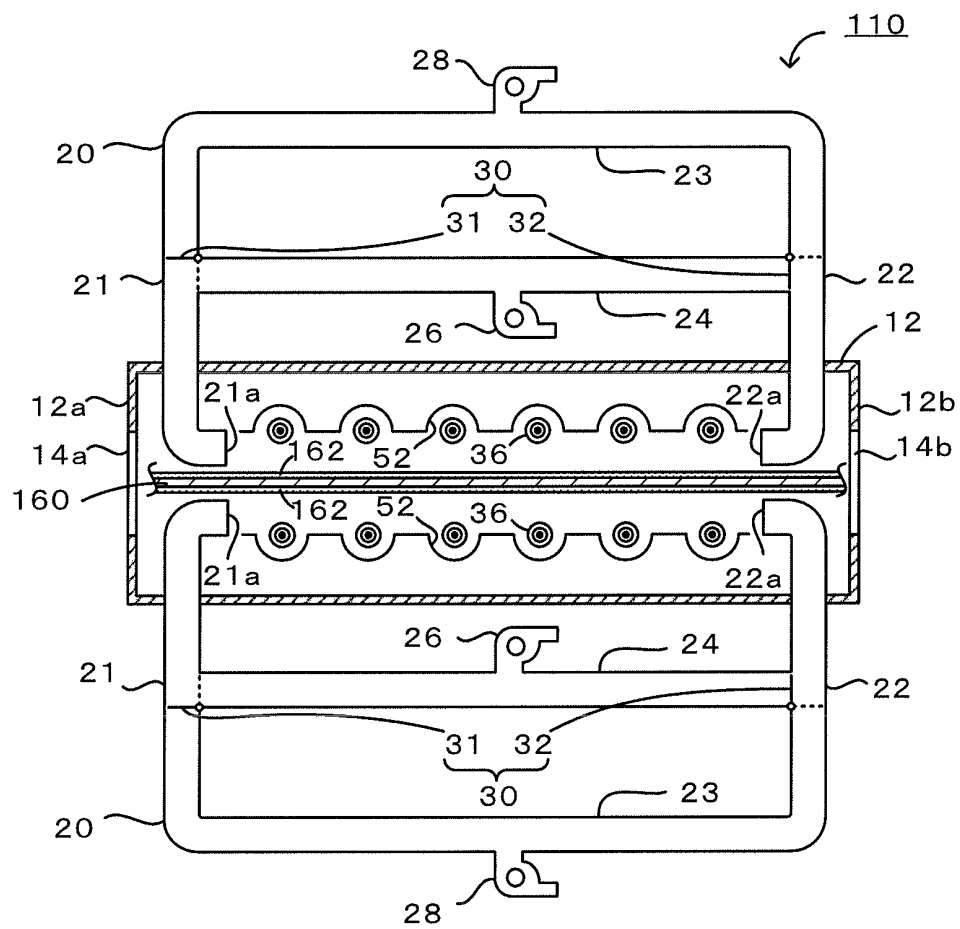


Fig. 8

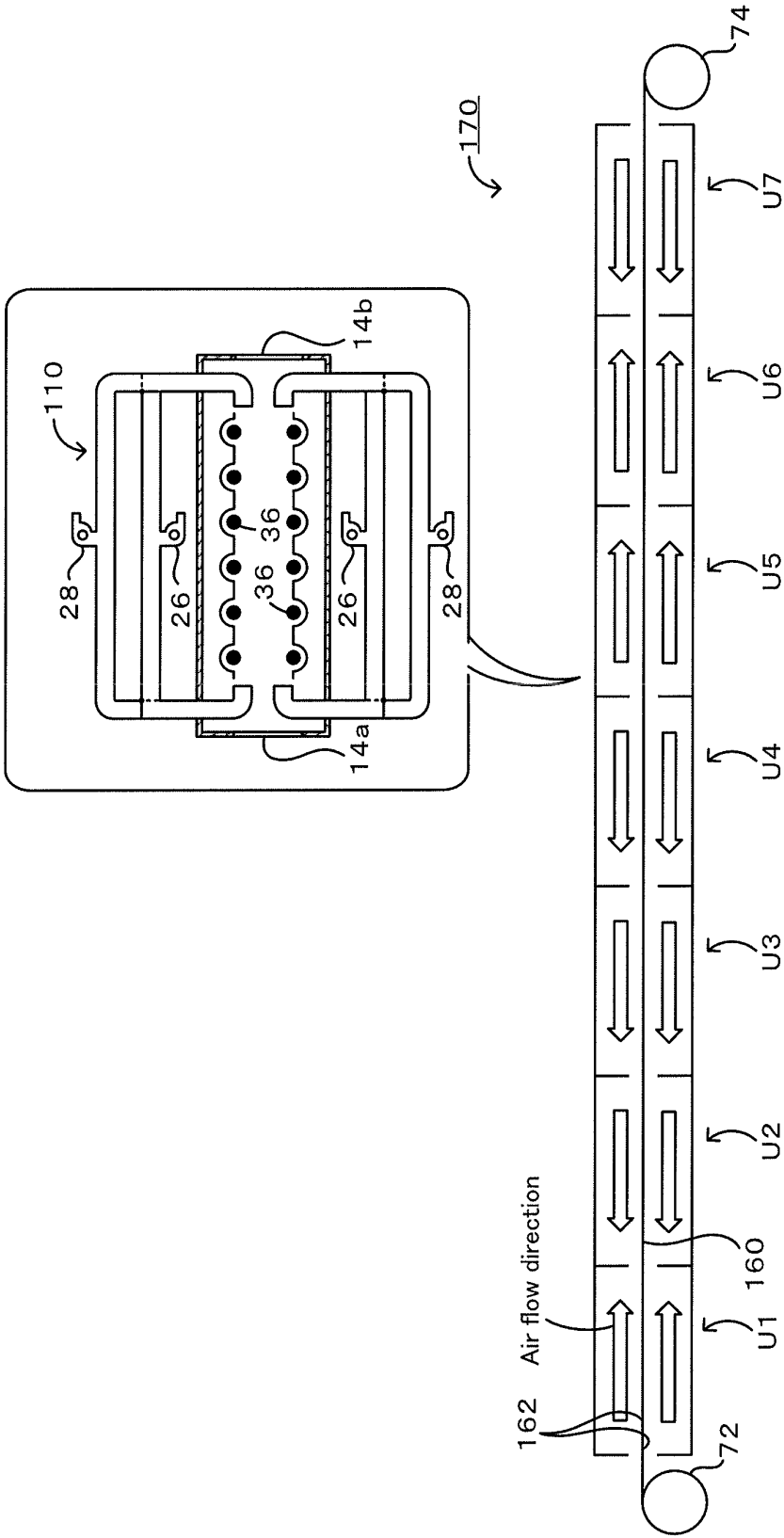
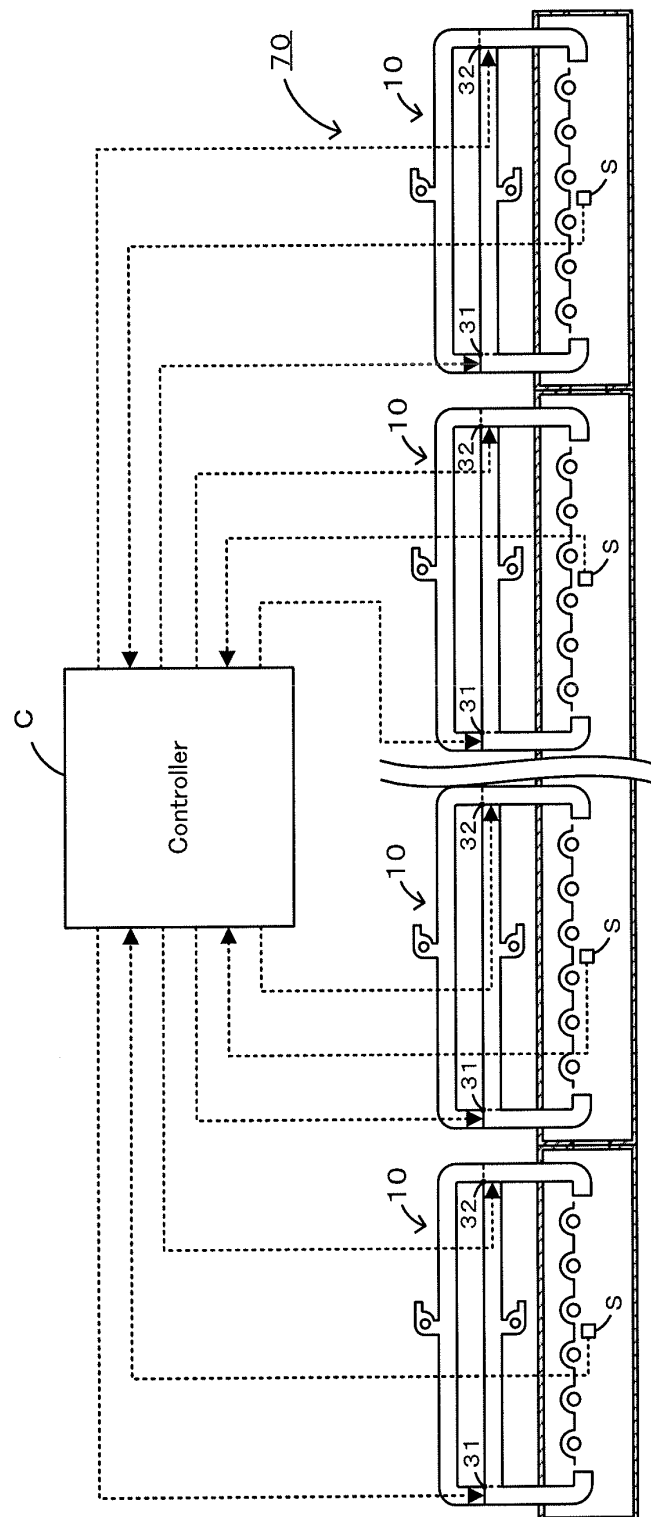


Fig. 9



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/050641

A. CLASSIFICATION OF SUBJECT MATTER

F26B13/10 (2006.01) i, B05C9/14 (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)

F26B13/10, B05C9/14

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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.
Y A	JP 10-337520 A (Hirano Tecseed Co., Ltd.), 22 December 1998 (22.12.1998), entire text; all drawings (Family: none)	1-6 7
Y A	JP 6-221760 A (Ichikin Engineering Co., Ltd.), 12 August 1994 (12.08.1994), entire text; all drawings (Family: none)	1-6 7
Y	JP 63-36871 A (Hirano Kinzoku Kabushiki Kaisha), 17 February 1988 (17.02.1988), claims; all drawings (Family: none)	2

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

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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

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Date of the actual completion of the international search

11 April, 2013 (11.04.13)

Date of mailing of the international search report

23 April, 2013 (23.04.13)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/050641

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 45642/1987 (Laid-open No. 152681/1988) (Trinity Industrial Corp.), 06 October 1988 (06.10.1988), entire text; fig. 1 (Family: none)	6

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2008302297 A [0003]
- JP 4790092 B [0009]
- JP 2012010631 A [0051]