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(54) **EXHAUST PURIFICATION APPARATUS AND UTILIZATION THEREOF**

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(57) **ABSTRACT**

The present invention relates to an exhaust purification apparatus for removing contaminants and odorous components from exhaust from cooking or the like, to an exhaust purification cabinet and cooking device equipped with the exhaust purification apparatus, and to a cooking system equipped with such a cooking device.

The exhaust purification apparatus in accordance with the present invention comprises a pretreatment unit **(117)** for trapping contaminants present in the exhaust and an optical treatment unit **(119)** comprising a photocatalytic filter **(62)** and disposed downstream of the pretreatment unit. The exhaust purification apparatus is disposed, for example, in an exhaust duct extending from a kitchen. The pretreatment unit **(117)** preferably comprises a dust collector **(50)** for trapping smoke particles present in the exhaust and/or a de-oiling filter **(20)** for trapping oil and fat components present in the exhaust. The exhaust purification cabinet comprises the exhaust purification apparatus contained in a cabinet having an exhaust path formed therein. The cooking device comprises the exhaust purification apparatus in a cooking device body comprising the cooking unit and having an exhaust path formed inside thereof. The cooking system comprises a plurality of cooking devices and a main duct connected to exhaust release openings of the cooking units.

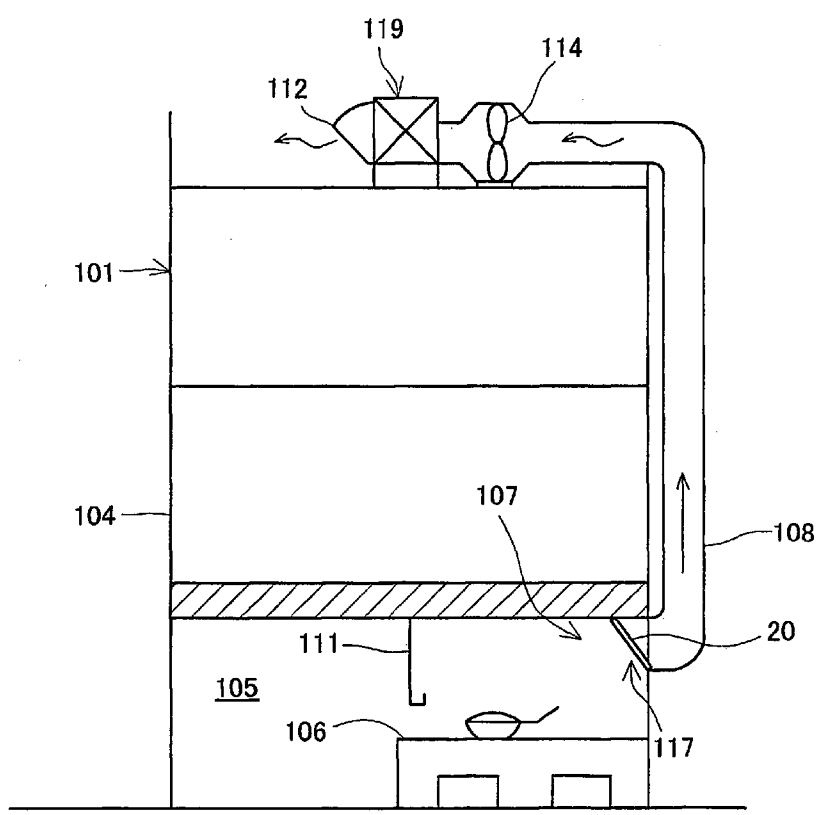


FIG.1

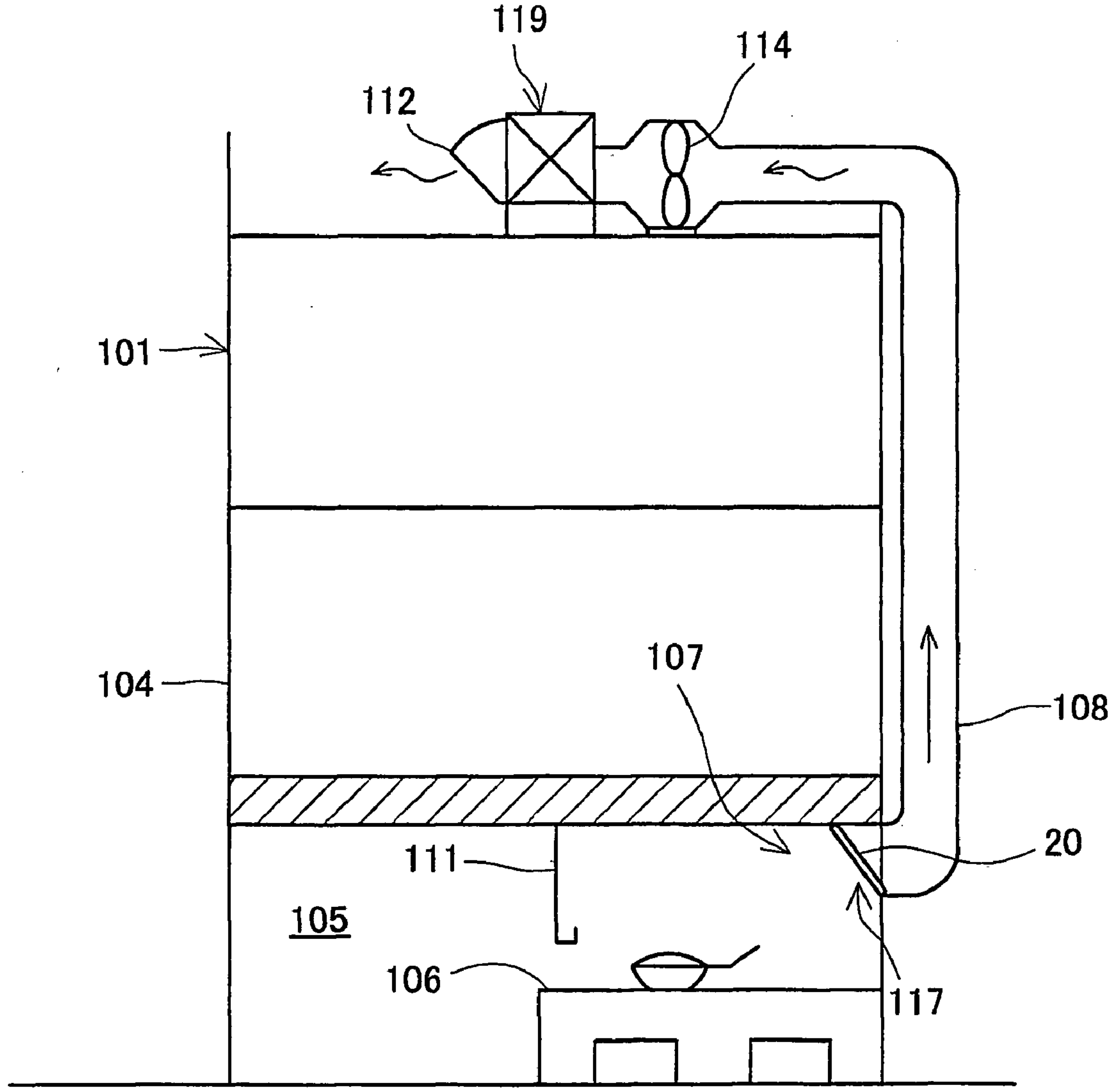


FIG.2

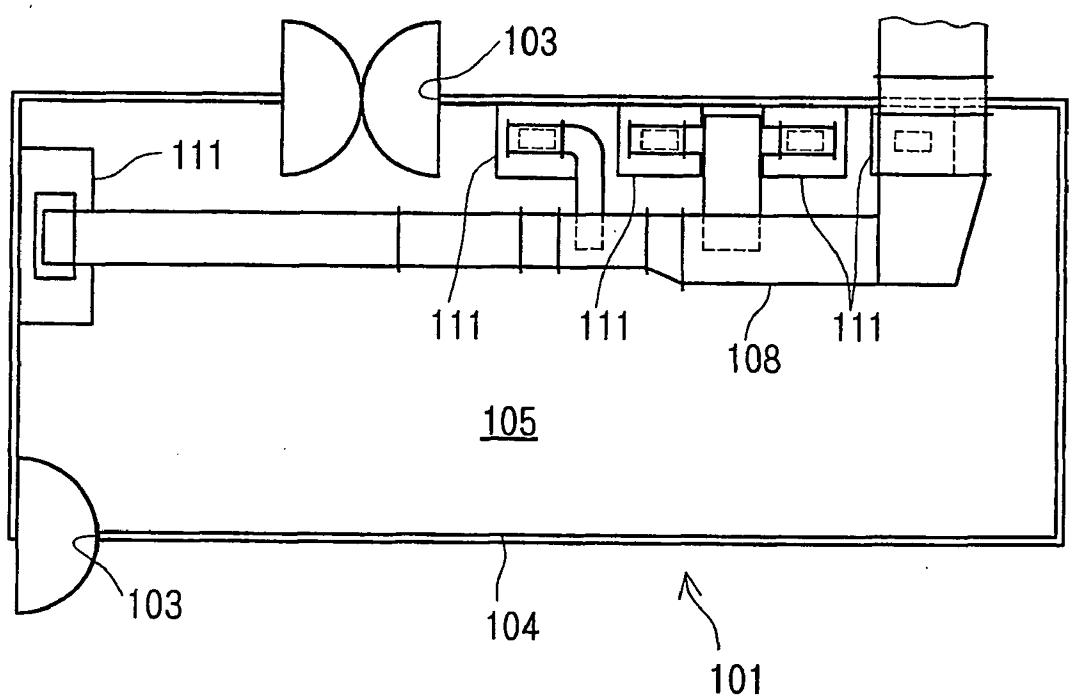


FIG.3

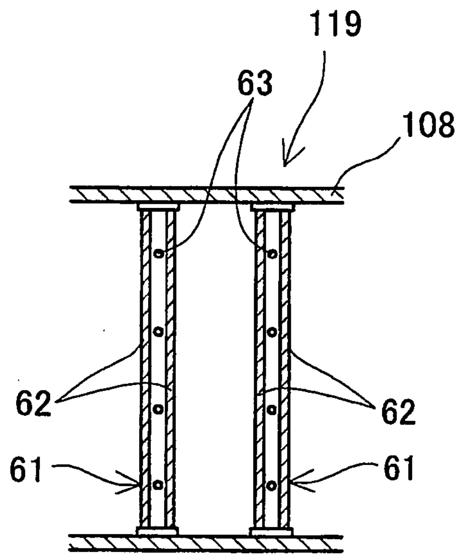


FIG.4

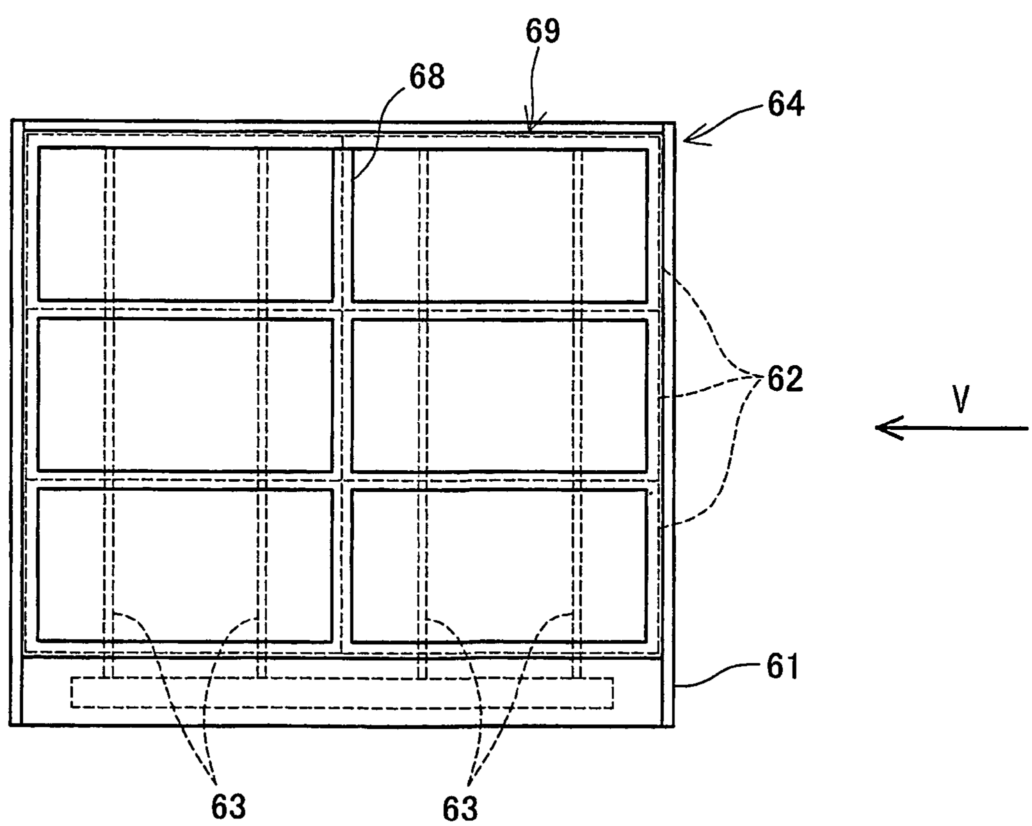


FIG.5

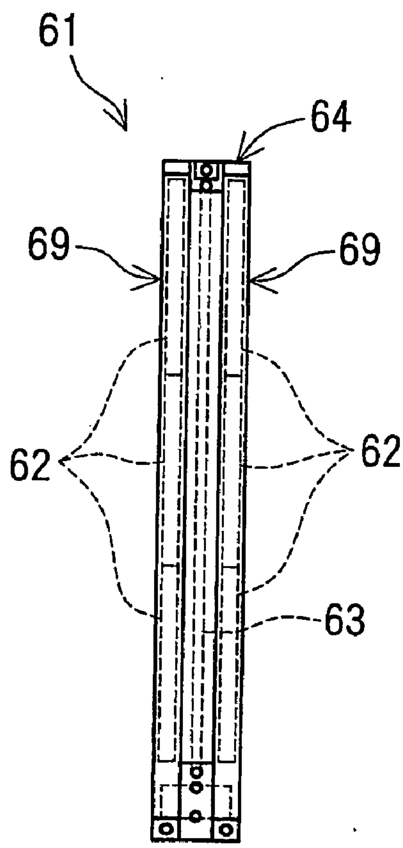


FIG.6

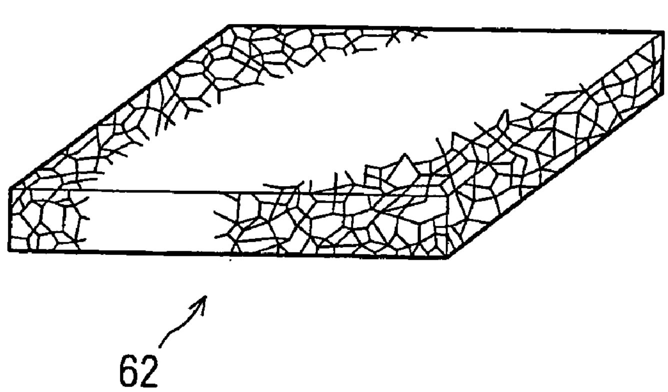


FIG.7

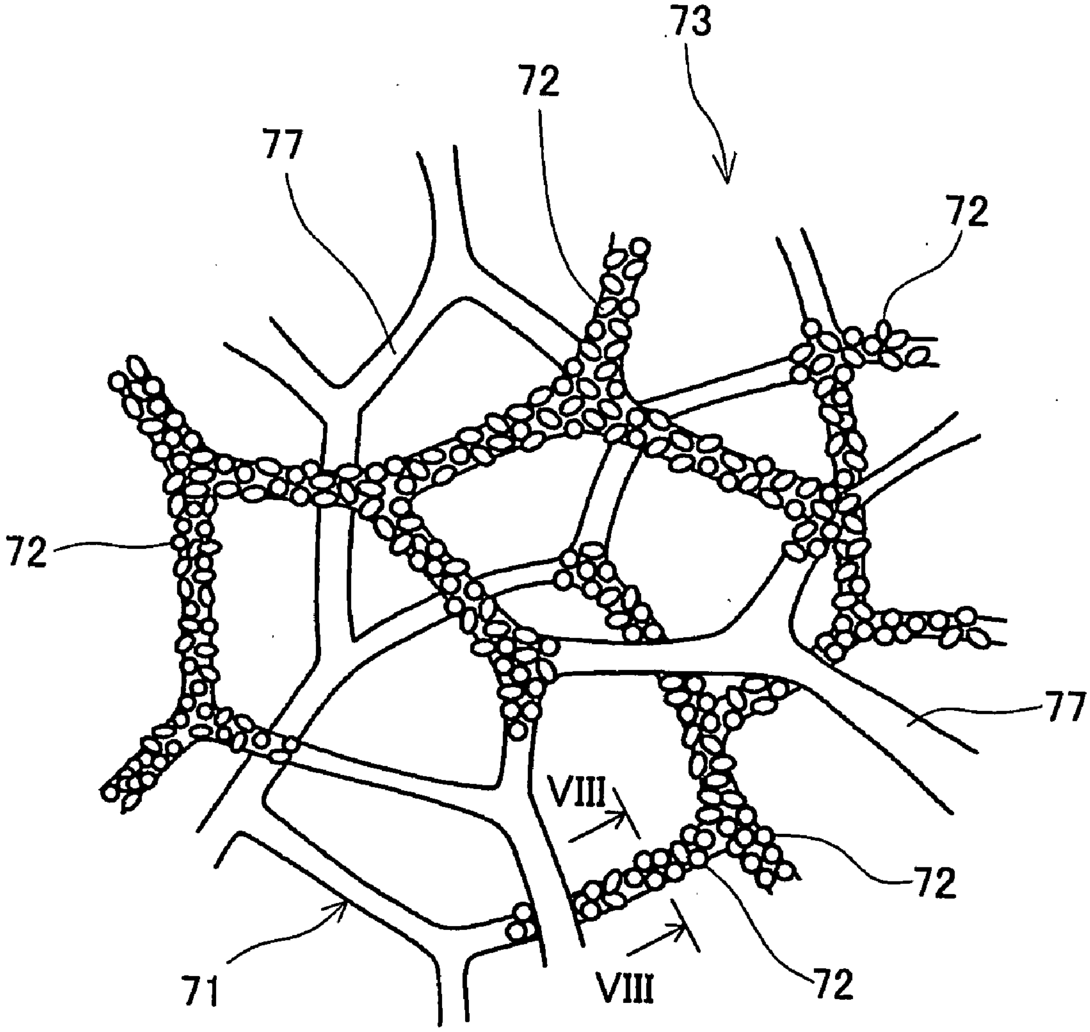


FIG.8

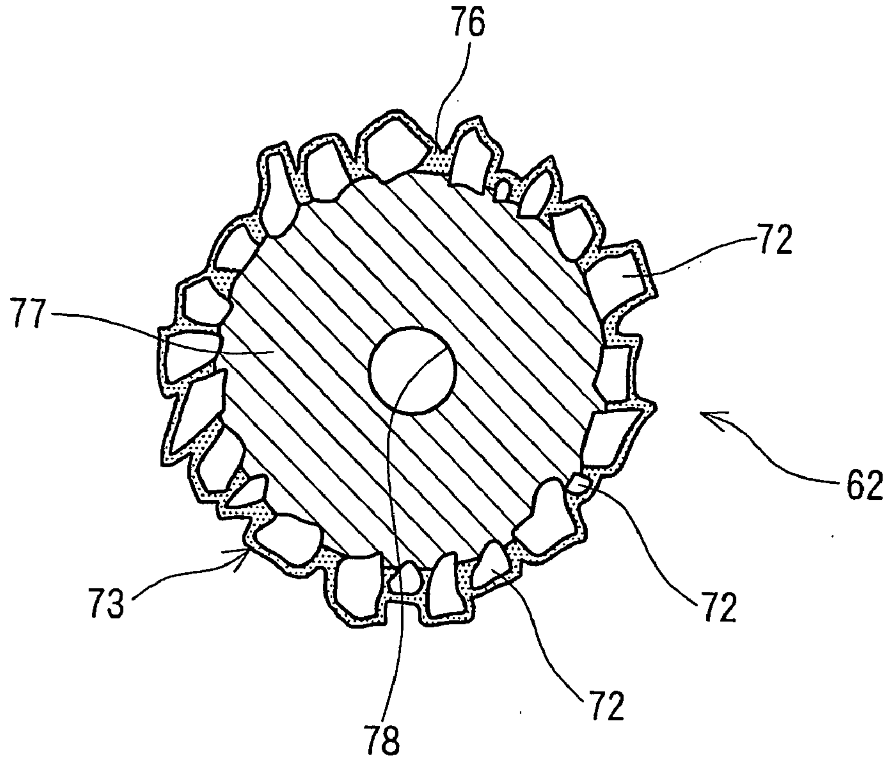


FIG.9

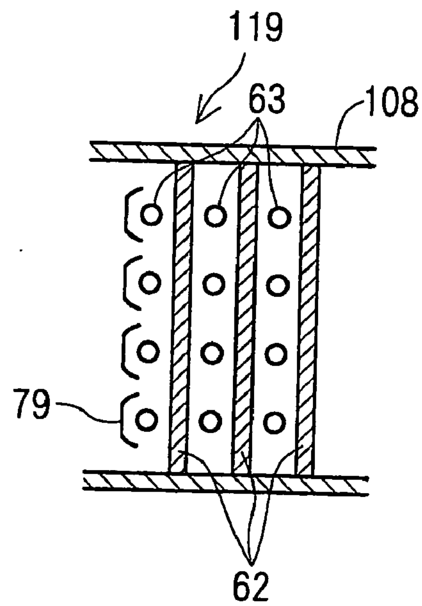


FIG. 10

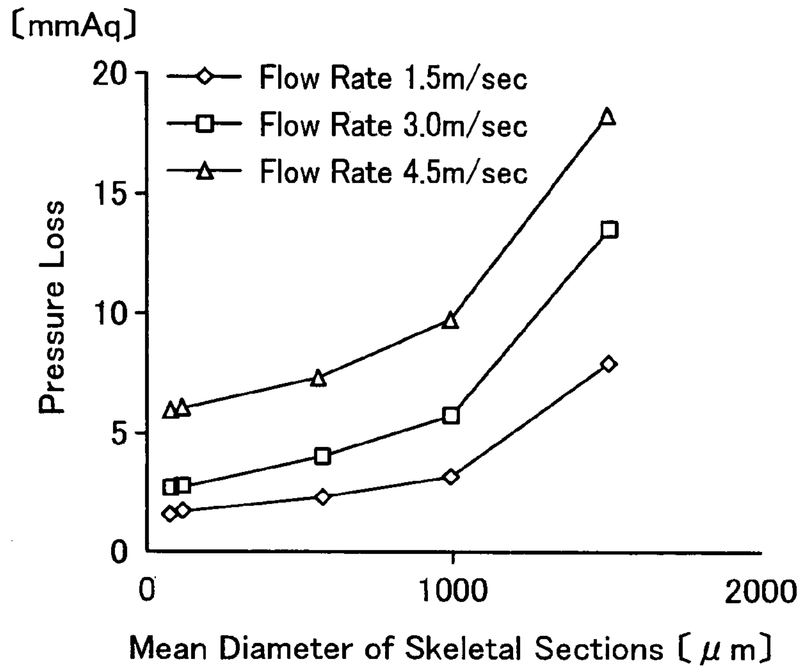

[mmAq]
Pressure Loss
20
15
10
5
0
Flow Rate 1.5m/sec
Flow Rate 3.0m/sec
Flow Rate 4.5m/sec
0
1000
2000
Mean Diameter of Skeletal Sections [μm]

FIG. 11

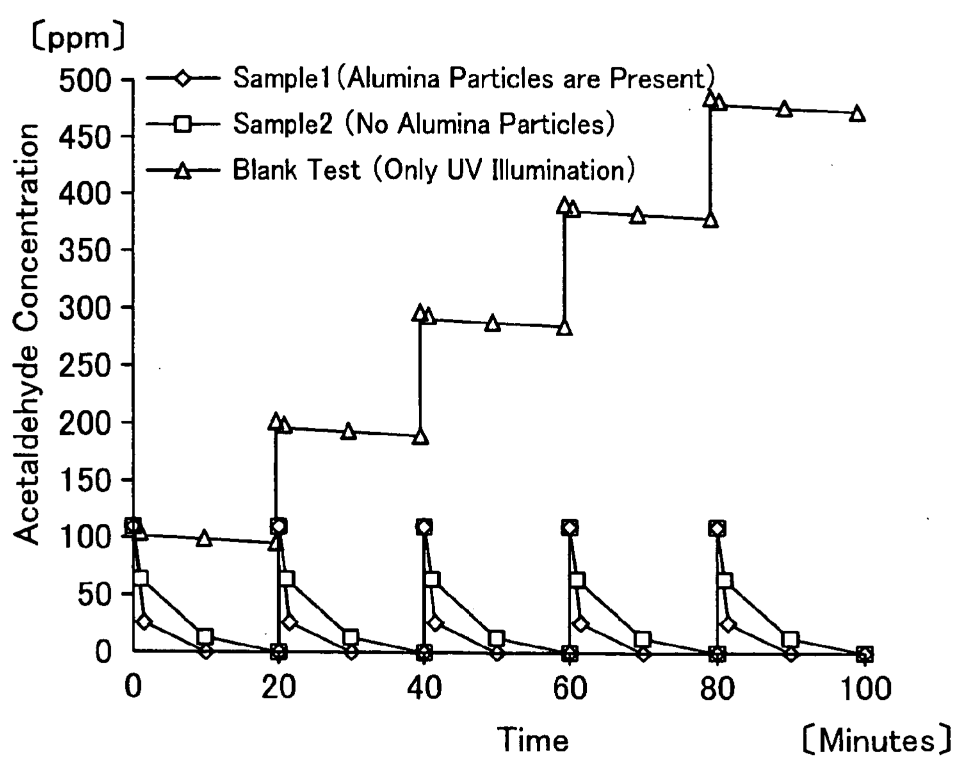

[ppm]
Acetaldehyde Concentration
500
450
400
350
300
250
200
150
100
50
0
Sample1 (Alumina Particles are Present)
Sample2 (No Alumina Particles)
Blank Test (Only UV Illumination)
0
20
40
60
80
100
Time
[Minutes]

FIG.12

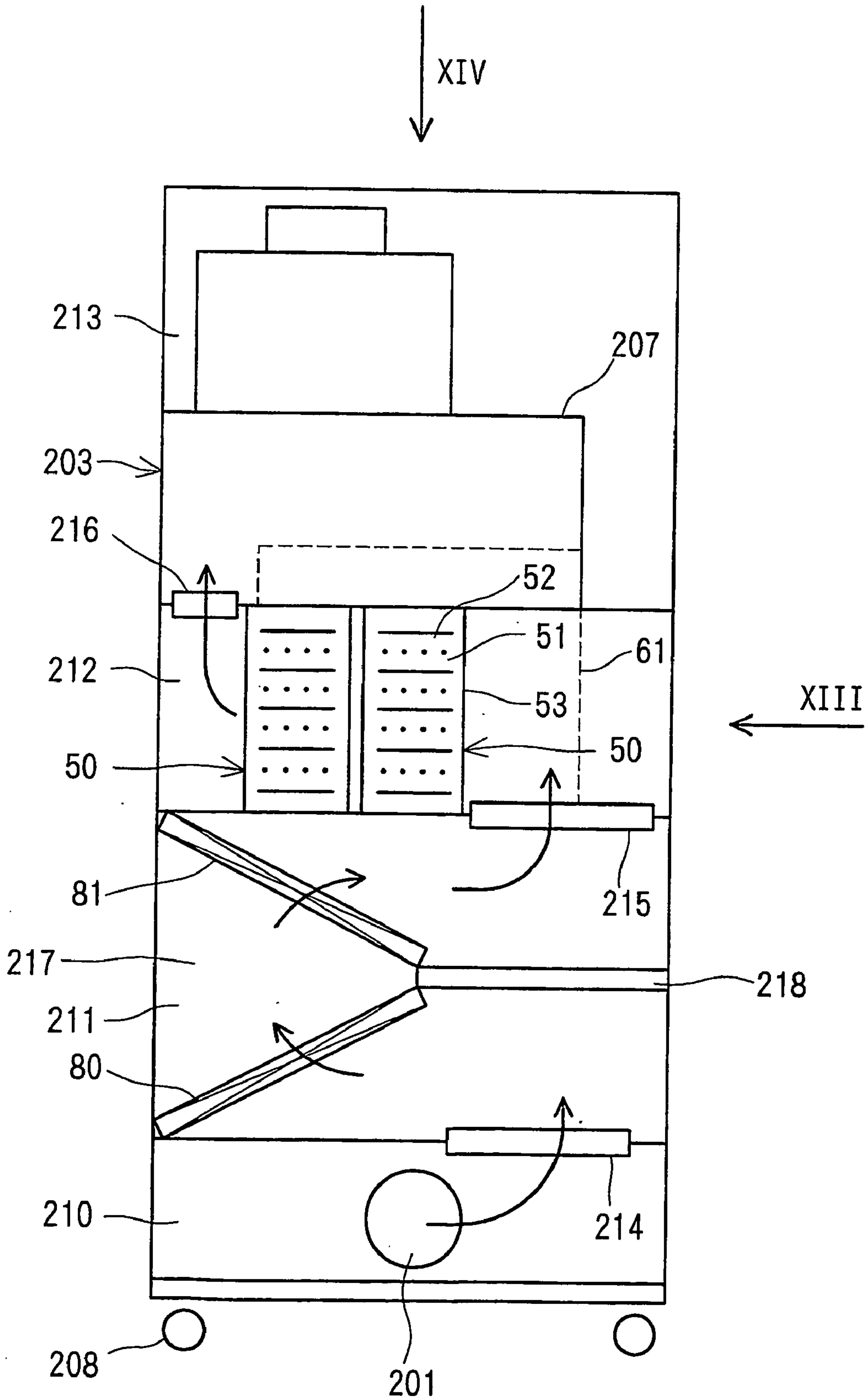

XIV
XIII
213
207
203
216
52
51
61
212
53
50
50
81
215
217
218
211
80
214
210
208
201

FIG.13

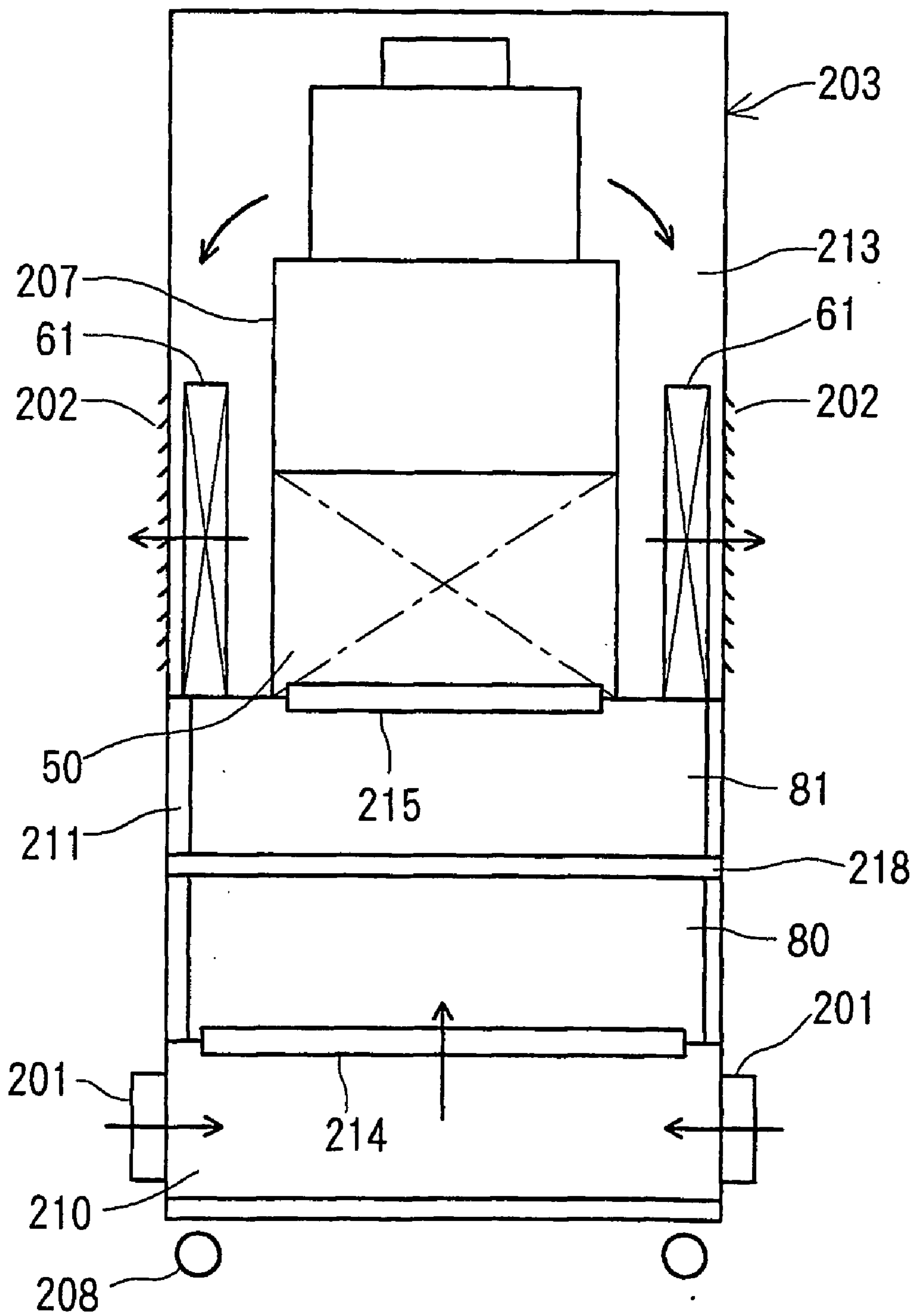


FIG.14

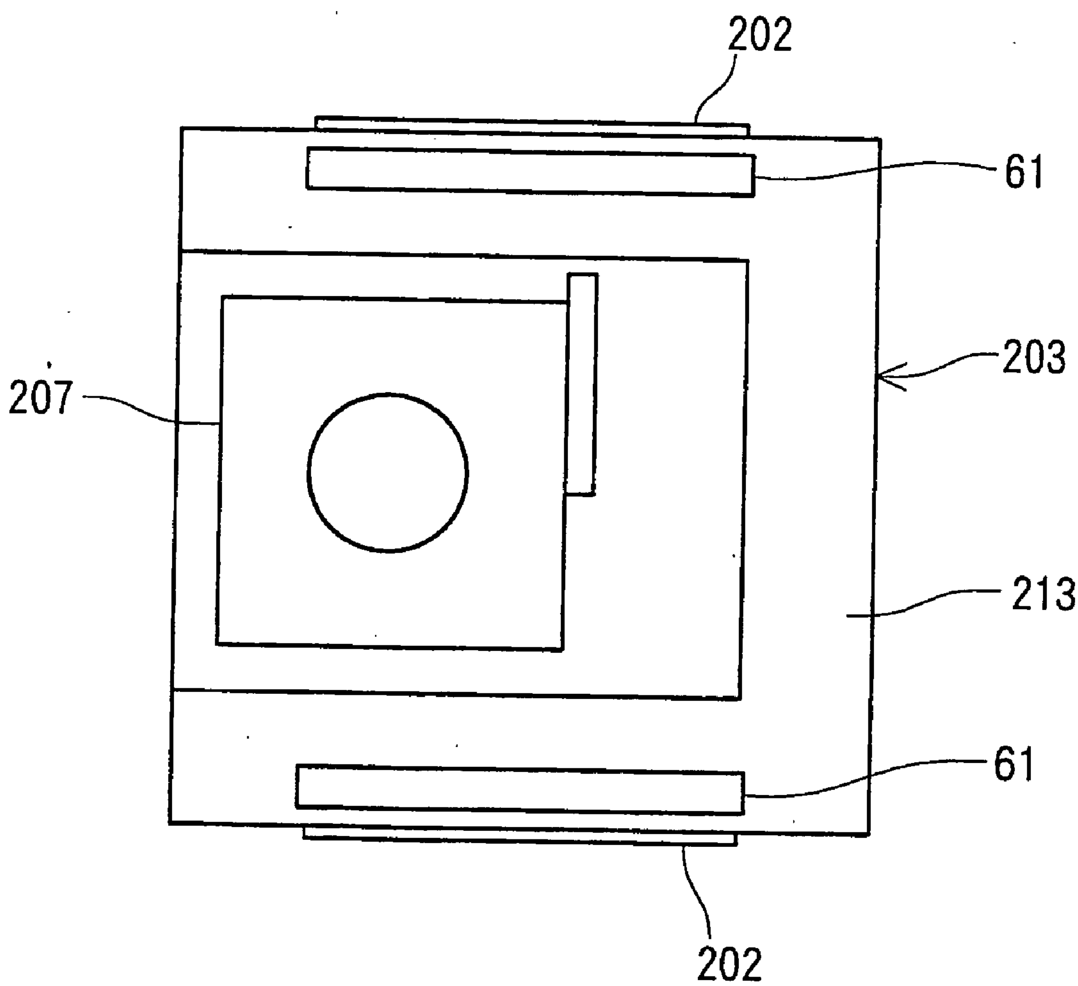


FIG.15

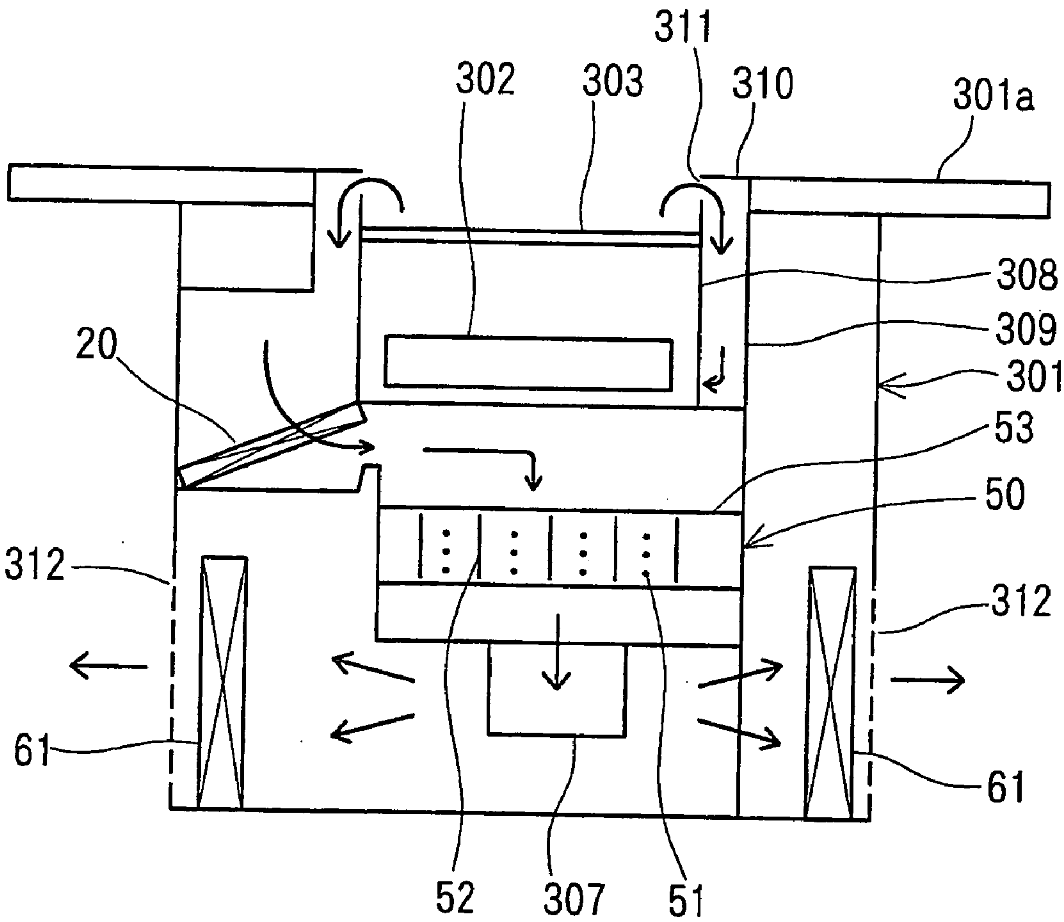


FIG. 16

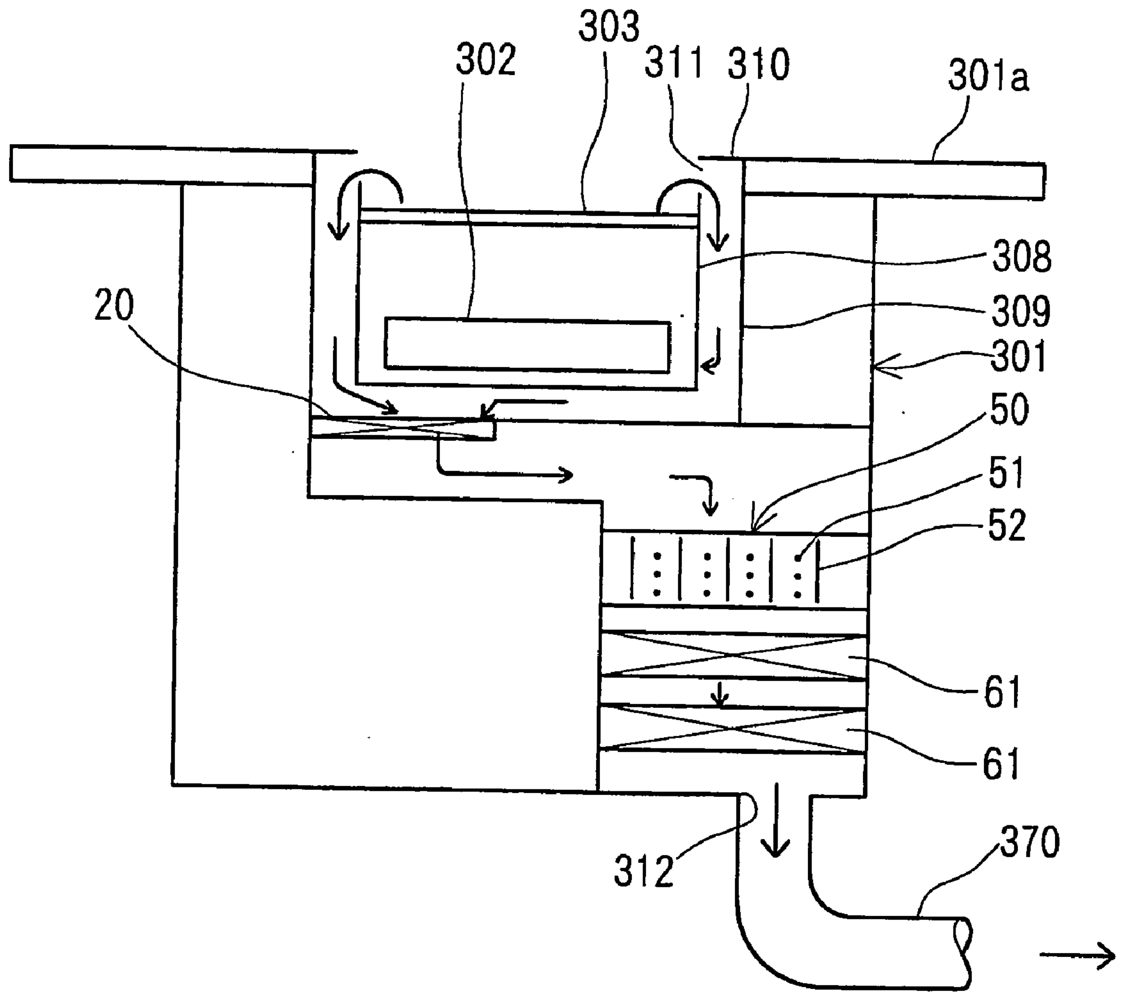
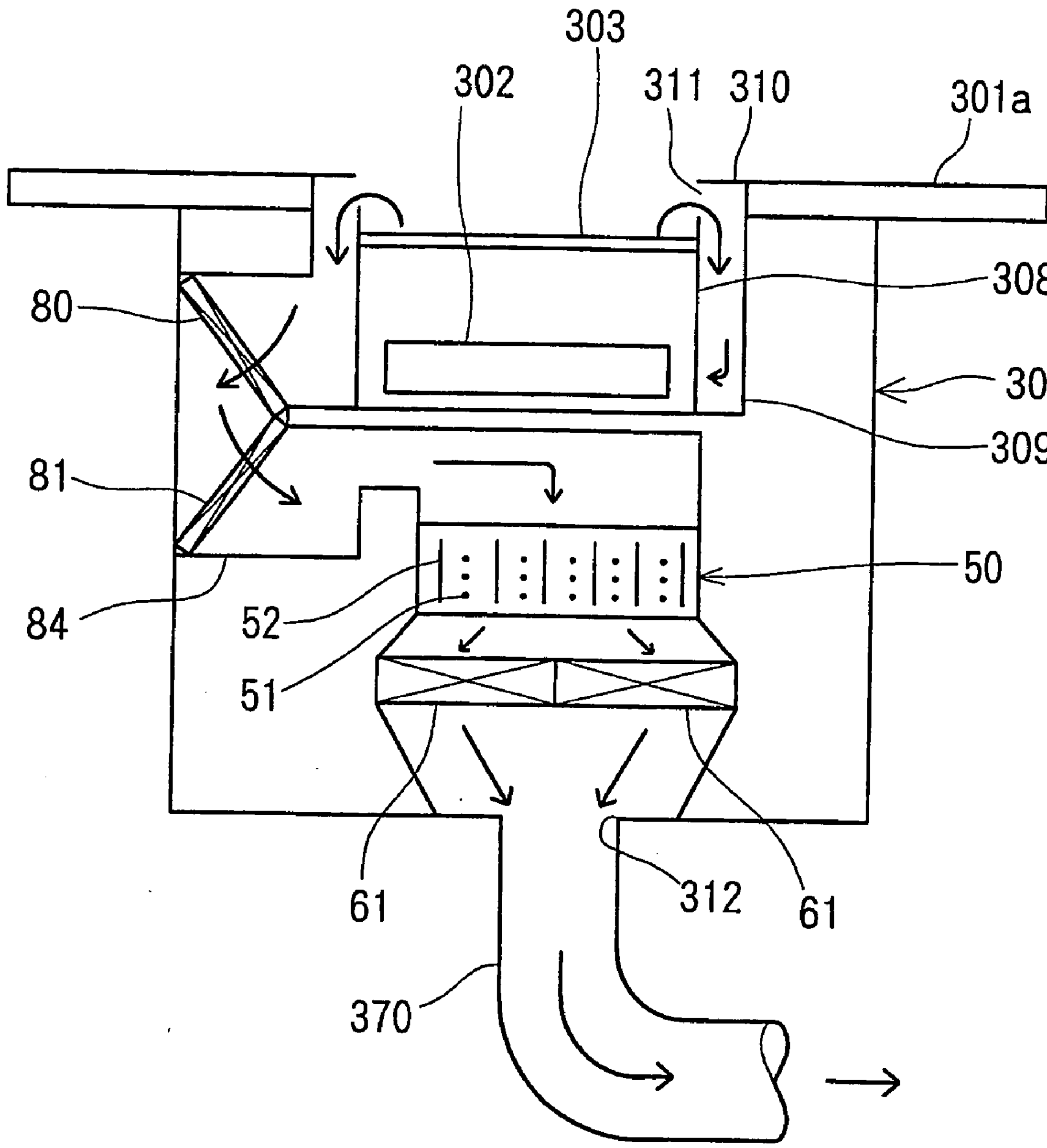


FIG.17



EXHAUST PURIFICATION APPARATUS AND UTILIZATION THEREOF

FIELD OF TECHNOLOGY

[0001] The present invention relates to an exhaust purification apparatus for the purification of exhaust. In particular, the present invention relates to an exhaust purification apparatus for the purification of exhaust containing contaminants and odorous components such as oil and fat components. Furthermore, the present invention also relates to an exhaust purification cabinet and a cooking device comprising the exhaust purification apparatus. Moreover, the present invention relates to a cooking system comprising the cooking device.

BACKGROUND TECHNOLOGY

[0002] When food is prepared, exhaust containing a large amount of contaminants and odorous components such as oil and fat components is generated. Japanese Utility Model Application Laid-open No. H1-97136 disclosed an apparatus for conducting purification treatment for removing the contaminants and odorous components from such an exhaust. In this apparatus, a fan and a filter are installed in the exhaust duct and contaminants are trapped with the filter from the exhaust sucked in by the fan. Furthermore, Japanese Patent Applications Laid-open Nos. H6-190223, H9-141024, and H1-224025 disclosed filters to be used for trapping contaminants present in the exhaust. Japanese Utility Model Application Laid-open No. H7-24423 disclosed an exhaust purification apparatus for trapping contaminants by passing the exhaust through a filter that is held in a tube and rotated. However, none of the above-mentioned exhaust purification apparatuses could effectively remove odorous components contained in the exhaust.

[0003] On the other hand, Japanese Patent Application Laid-open No. H11-207136 disclosed an exhaust purification apparatus in which a filter (photocatalytic filter) supporting a photocatalyst was irradiated with UV radiation and the oil and fat components or odorous components contained in the exhaust were decomposed by the photocatalytic action. A filter supporting a photocatalyst was also disclosed in Japanese Patent Application Laid open. No. 2001-38218. However, when exhaust containing a comparatively large amount of contaminants is passed through such a photocatalytic filter, the surface of the photocatalytic filter is covered with the contaminants (oil and fat components, dust, tar-like substances, and the like) trapped by the filter. As a result, in certain cases, the photocatalyst is shielded from UV radiation and the photocatalytic effect is not demonstrated.

DISCLOSURE OF THE INVENTION

[0004] It is an object of the present invention to provide an exhaust purification apparatus capable of purifying the exhaust containing contaminants (oil and fat components and the like) and odorous components generated by cooking. Another object of the present invention is to provide an exhaust purification cabinet equipped with the exhaust purification apparatus. Yet another object of the present invention is to provide a cooking device equipped with the exhaust purification apparatus. Still another object of the present invention is to provide a cooking system equipped with the cooking device.

[0005] The exhaust purification apparatus in accordance with the present invention is disposed in an exhaust channel and comprises a pretreatment unit for trapping contaminants present in the exhaust and an optical treatment unit having a photocatalytic filter. The optical treatment unit is disposed downstream of the pretreatment unit, with respect to the flow direction of the exhaust that passes through the exhaust channel.

[0006] With the exhaust purification apparatus of such a configuration, at least part of the contaminants (oil particles, smoke particles, dust and other nonvolatile components) present in the exhaust are trapped in the pretreatment unit. As a result, the amount of the contaminants contained in the exhaust (exhaust treated in the pretreatment unit) supplied to the photocatalytic filter is decreased. Therefore, the problem associated with the performance degradation of the photocatalytic filter caused by adhesion of the contaminants is resolved or alleviated.

[0007] In a preferred configuration of the exhaust purification apparatus in accordance with the present invention, the photocatalytic filter comprises a ceramic substrate and a photocatalyst supported on the ceramic substrate. The ceramic substrate comprises a ceramic porous body having a three-dimensional net-like structure and ceramic particles held in the ceramic porous body. The mean particle size of the ceramic particles is from no less than 1 μm to no more than 100 μm.

[0008] In a preferred photocatalytic filter, the mean diameter of the skeletal sections of the ceramic porous body is from no less than 100 μm to no more than 1000 μm. Furthermore, the photocatalytic filter more preferably satisfies at least one of the following three conditions: (1) a porosity is from no less than 65% to no more than 95%; (2) a bulk density is from no less than 0.15 g/cm^3 to no more than 0.60 g/cm^3; and (3) the number of cells is from no less than 10 cells per 25 mm to no more than 30 cells per 25 mm.

[0009] In yet another preferred configuration of the exhaust purification apparatus in accordance with the present invention, the pretreatment unit comprises a particulate filter for trapping particles (oil particles, smoke particles, dust and the like) present in the exhaust. A dust collector for trapping smoke particles present in the exhaust and a de-oiling filter for trapping oil and fat components (oil particles and the like) present in the exhaust can be used as such a particulate filter. The de-oiling filter preferably has a capacity of removing no less than 70 wt. % (more preferably no less than 90 wt. %, and yet more preferably no less than 95 wt. %) of oil and fat components present in the exhaust. The percentage of oil and fat components that can be removed from the exhaust when it passes through the de-oiling filter is called the "oil removal rate" of the de-oiling filter. When a plurality of de-oiling filters (for example, multi-layer plate-like filters) are provided in the pretreatment unit, the total percentage of the oil and fat components removed by those de-oiling filters is considered as the oil removal rate.

[0010] In yet another preferred modification of the exhaust purification apparatus in accordance with the present invention, the pretreatment unit comprises a de-oiling filter for trapping oil and fat components present in the exhaust and a dust collector for trapping smoke particles present in the exhaust. Here, the dust collector is disposed downstream of the de-oiling filter. It is also preferred that the sectional area of the exhaust path at each flow inlet side of the zone where the de-oiling filter, dust collector, and photocatalytic filter are located increases in the order of description.

[0011] In yet another exhaust purification apparatus provided in accordance with the present invention, any of the above-described exhaust purification apparatuses in accordance with the present invention further comprises a cabinet comprising an intake opening, an exhaust release opening.

[0012] In yet another exhaust purification apparatus provided in accordance with the present invention, any of the above-described exhaust purification apparatuses in accordance with the present further comprises a cooking device body comprising a cooking unit for heating and cooking the product which is to be cooked, an intake opening for sucking in the exhaust from the cooking unit, an exhaust release opening for releasing the exhaust that was purified, and an exhaust path passing from the intake opening to the exhaust release opening.

[0013] In any of the exhaust purification apparatuses in accordance with the present, invention, the optical treatment unit preferably further comprises a light source for illuminating the photocatalytic filter with light. Further, it is preferred that an ozone supply means for supplying ozone into the exhaust channel be further provided.

[0014] The exhaust purification cabinet provided in accordance with the present invention contains the exhaust purification apparatus in accordance with the present invention in a cabinet comprising an intake opening, an exhaust release opening, and an exhaust path from the intake opening to the exhaust release opening.

[0015] The cooking device provided in accordance with the present invention comprises the exhaust purification apparatus in accordance with the present invention in a cooking device body comprising a cooking unit for heating and cooking the product which is to be cooked, an intake opening for sucking in the exhaust from the cooking unit, an exhaust release opening for releasing the exhaust that was purified, and an exhaust path passing from the intake opening to the exhaust release opening.

[0016] Further, the cooking system provided in accordance with the present invention comprises a plurality of the cooking devices in accordance with the present invention and a main duct connected to exhaust release openings of cooking devices.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] **FIG. 1** is an explanatory drawing illustrating schematically the exhaust purification apparatus of the first embodiment.

[0018] **FIG. 2** is an explanatory drawing illustrating schematically a kitchen.

[0019] **FIG. 3** is a cross-sectional view illustrating schematically the optical treatment unit in the exhaust purification apparatus of the first embodiment.

[0020] **FIG. 4** is a plan view illustrating the photocatalytic unit.

[0021] **FIG. 5** is a view along the arrow in the V direction shown in **FIG. 4**.

[0022] **FIG. 6** is a perspective view illustrating schematically a photocatalytic filter.

[0023] **FIG. 7** is an explanatory drawing illustrating the structure of the ceramic substrate.

[0024] **FIG. 8** is a cross-sectional view along the VIII-VIII line shown in **FIG. 7**.

[0025] **FIG. 9** is a cross-sectional view showing schematically another configuration of the optical treatment unit in the exhaust purification apparatus of the first embodiment.

[0026] **FIG. 10** is a characteristic diagram illustrating the relationship between the mean diameter of skeletal sections and pressure loss.

[0027] **FIG. 11** is a characteristic diagram illustrating the acetaldehyde decomposition capacity of the photocatalytic filter.

[0028] **FIG. 12** is a cross-sectional view showing schematically the exhaust purification cabinet of the third embodiment.

[0029] **FIG. 13** is a view along the arrow in the XIII direction shown in **FIG. 12**.

[0030] **FIG. 14** is a view along the arrow in the XIV direction shown in **FIG. 12**.

[0031] **FIG. 15** is a cross-sectional view showing schematically the cooking device of the fourth embodiment.

[0032] **FIG. 16** is a cross-sectional view showing schematically the cooking device constituting the cooking system of the fifth embodiment.

[0033] **FIG. 17** is a cross-sectional view showing schematically the cooking device constituting the cooking system of the sixth embodiment.

BEST MODE FOR CARRYING OUT THE PRESENT INVENTION

[0034] The best mode for carrying out the present invention will be described below. It is preferred that the photocatalytic filter used in the exhaust purification apparatus in accordance with the present invention comprises a ceramic substrate wherein ceramic particles are supported on the surface of a ceramic porous body. Owing to the presence of ceramic particles, peaks and valleys are formed on the surface of the ceramic porous body. Because of the anchor effect produced by those peaks and valleys, the photocatalyst can be held with high stability on the ceramic substrate. Furthermore, because the presence of such peaks and valleys increases the surface area of the ceramic porous body a large amount of the catalyst can be supported per unit surface area. Moreover, those peaks and valleys can increase the surface area of the photocatalytic filter per unit volume thereof. Due to the above-described effects, the contact between the exhaust and the photocatalyst is improved and the exhaust can be purified with good efficiency.

[0035] Here, ceramic particles with a mean particle size of from no less than 1 μm to no more than 100 μm are preferred as the above-mentioned ceramic particles, and particles with a mean particle size of from no less than 20 μm to no more than 50 μm are even more preferred. If the mean particle size of the ceramic particles is less than 1 μm, the efficiency of forming peaks and valleys on the surface of the ceramic porous body is decreased. On the other hand, if the mean particle size of the ceramic particles exceeds 100 μm, such ceramic particles are difficult to hold with good stability on the surface of the ceramic porous body.

[0036] It is also preferred that the ceramic porous body be composed of skeletal sections with a diameter of from no less than 100 μm to no more than 1000 μm. The ceramic porous body with a mean diameter of skeletal sections of no less than 100 μm (more preferably, no less than 300 μm) has an appropriate mechanical strength. Therefore, it can be easily manufactured and handled. If the mean diameter of the skeletal sections is more than 1000 μm, the light transmissivity of the photocatalytic filter comprising the ceramic porous body is degraded and the photocatalyst held inside the photocatalytic filter sometimes cannot be adequately used. Furthermore, pressure loss occurring when the exhaust passes through the photocatalytic filter sometimes becomes too high.

[0037] Furthermore, the photocatalytic filter preferably satisfies at least one of the following three conditions: (1) a porosity is from no less than 65% to no more than 95%; (2) a bulk density is from no less than 0.15 g/cm^3 to no more than 0.60 g/cm^3; and (3) the number of cells is from no less than 10 cells per 25 mm to no more than 30 cells per 25 mm.

[0038] A photocatalytic filter with a porosity of no more than 95%, a bulk density of no less than 0.15 g/cm^3, and a number of cells of no more than 30 cells per 25 mm has an appropriate mechanical strength. Therefore, it can be easily manufactured and handled. If the porosity of the photocatalytic filter is less than 65%, or the bulk density is more than 0.60 g/cm^3, or the number of cells is less than 10 cells per 25 mm, the pressure loss in the exhaust passing therethrough sometimes becomes too high. Furthermore, in such a photocatalytic filter, the quantity of light reaching the inside of the filter tends to decrease. Furthermore, the contact ratio of the photocatalyst and the odorous components (mainly gaseous organic compounds) present in the exhaust decreases, and the photocatalytic efficiency sometimes drops.

[0039] The photocatalytic filter has a light transmissivity, preferably, of from no less than 10% to no more than 50% (preferably from no less than 20% to no more than 50%) at a thickness of 5 mm. In the photocatalytic filter with a light transmissivity of no less than 10%, light can penetrate to the inner portions of the filter. Therefore, the photocatalyst supported by the photocatalytic filter can be used effectively. The light transmissivity within the above-described range can be realized if at least one (preferably two, even more preferably all) of the above-described three conditions is satisfied.

[0040] The photocatalytic filter can be advantageously obtained by a manufacturing process comprising the steps of: (a) impregnating an organic porous body having a three-dimensional net-like structure with a slurry containing a ceramic fine powder and a binding material; (b) causing ceramic particles to adhere to the above-mentioned undried slurry; (c) heating to burn out the organic porous body and to produce a ceramic substrate having ceramic particles supported on a ceramic porous body; and (d) coating a photocatalytic layer containing a photocatalyst on the surface of a ceramic substrate.

[0041] A more specific example of the manufacturing method will be described herein below.

[0042] First, a fine ceramic powder (one or two or more of the fine powders selected from alumina, silica, and mullite can be used for this purpose) and a binder as a binding material (any of organic binders such as dextrin, methyl cellulose, and polyvinyl alcohol, or inorganic binders such as clay and sodium silicate can be used) are added to an appropriate amount of water and stirred to prepare a slurry for the formation of a ceramic porous body. Then, an organic porous body (foamed urethane resin or the like) having a three-dimensional net-like structure is impregnated with the slurry.

[0043] Ceramic particles (one or two or more of the fine powders selected from alumina, silica, and mullite can be used for this purpose) are then sprinkled over the organic porous body, which is wetted with the slurry. As a result, the ceramic particles adhere to the undried slurry.

[0044] The slurry is then dried and fired to burn out the organic porous body and also to integrate it by sintering the ceramic particles and fine ceramic powder constituting the slurry. As a result, as shown in **FIG. 7** and **FIG. 8, a** ceramic substrate **73** is formed which comprises a ceramic porous body **71** formed by the sintered particles of the fine ceramic powder and ceramic particles **72** integrally held by (sintered to) the surface of the ceramic porous body. Furthermore, as shown in **FIG. 8**, burn-out marks **78** are formed.

[0045] A photocatalytic slurry is then prepared, this slurry containing a photocatalyst as the main component and also comprising an organic or inorganic binder. The ceramic substrate **73** is impregnated with the photocatalytic slurry, followed by drying and firing. As a result, a photocatalytic layer **76** covering the surface of the ceramic substrate **73** (see **FIG. 8**) is formed. A photocatalytic filter **62** is thus obtained.

[0046] One or two or more compounds selected from titanium oxide, tungsten oxide, zinc oxide, vanadium oxide, and zirconium oxide can be used as the photocatalyst. Titanium oxide is typically used for this purpose.

[0047] In an optical treatment unit, the photocatalytic filters are preferably arranged on both sides, opposite each other so as to sandwich the light source. With such a configuration, light illuminated from the light source to all sides can be used effectively. A light source emitting a large amount of light with a wavelength at which the photocatalyst can function effectively is preferably used according to the type of the photocatalyst supported on the photocatalytic filter. Typically, a UV lamp such as a low-pressure mercury lamp, an ultrahigh-pressure mercury lamp, or fluorescent lamp such as a so-called black light is used. When the photocatalyst is titanium oxide, it is especially preferred that a UV lamp emitting UV radiation (for example, UV radiation with a peak of from no less than 360 nm and no more than 380 nm) with a wavelength of from no less than 300 nm to no more than 420 nm be employed.

[0048] The exhaust purification apparatus in accordance with the present invention can have a structure additionally comprising an ozone supply means for supplying ozone into the exhaust channel. Producing a strong oxidizing effect by ozone in addition to the photocatalytic effect makes it possible to treat the odorous components and/or contaminants present in the exhaust with even higher efficiency. A UV lamp (for example, a low-pressure mercury lamp) emitting light with a wavelength of about 185 nm can be used as the ozone supply means. Ozone is generated by illuminating oxygen present inside the exhaust path with light with a wavelength of about 185 nm.

[0049] This UV lamp may be also employed as a light source for illuminating the photocatalytic filter with light.

[0050] Examples of the dust collector used in the exhaust purification apparatus in accordance with the present invention include an electric dust collector, a filtration dust collector, an acoustic dust collector, or a centrifugal dust collector. Typically, an electric dust collector is used. The dust collector is preferably disposed downstream of the de-oiling filter.

[0051] A typical de-oiling filter called a grease filter, grease separator, grease extractor, or the like can be used as the de-oiling filter employed in the exhaust purification apparatus in accordance with the present invention. The preferred filter among those de-oiling filters is a filter that has an oil removal rate of no less than 70 wt. %, preferably no less than 90 wt. %, and even more preferably no less than 95 wt. %. The de-oiling filter is preferably composed of a nonflammable material such as metallic fibers (for example, aluminum fibers) or a material with low flammability, such as glass fibers. A de-oiling filter composed of metallic wire such as steel wool (for example, stainless steel wool) or metallic fibers such as metallic ribbons can be used.

[0052] Such a de-oiling filter can be arranged so that the exhaust passes a plurality of times through the materials constituting the filter, as it passes through the pretreatment unit (that is, so that the exhaust flow is intercepted in a plurality of places by the materials constituting the filter). For example, a configuration can be employed in which the de-oiling filters are supported as plates and a plurality of such plate-like filters are arranged so as to intercept each exhaust flow.

[0053] From the standpoint of purification efficiency, it is preferred that the exhaust be passed at a comparatively low velocity to the dust collector (in particular, electric dust collector) or photocatalytic filter of all the components constituting the exhaust purification apparatus in accordance with the present invention. The flow velocity of the exhaust can be adjusted, for example, by varying the sectional area of the opening in the exhaust channel (cross sectional area of the exhaust path). More specifically, upstream (inflow side) of the de-oiling filter, the cross sectional area of the exhaust path can be decreased to increase the flow velocity, and upstream of the dust collector, the cross sectional area can be increased to increase the flow velocity. Furthermore, it is preferred that the cross sectional area be further increased and dispersion (diffusion) of the exhaust be caused upstream of the photocatalytic filter. With such a configuration, exhaust streams with respectively appropriate flow velocities are supplied to the de-oiling filter, dust collector, and photocatalytic filter, and contaminants of various types can be effectively removed.

[0054] Further, in addition to the above-described method of changing the cross sectional area of the exhaust path, decreasing the flow velocity by changing the flow of exhaust with a baffle provided inside the exhaust path can be used as a means for adjusting the flow velocity of the exhaust. Alternatively a fan may be installed upstream of the deoiling filter to increase the flow velocity of the exhaust supplied to the de-oiling filter.

[0055] The exhaust purification apparatus in accordance with the present invention can further comprise a cabinet comprising an intake opening, an exhaust release opening, and an exhaust path passing from the intake opening to the exhaust release opening. The exhaust purification apparatus comprising such a cabinet (exhaust purification cabinet) can be moved easily to any installation site. Therefore, the utility of the exhaust purification apparatus is increased. Furthermore, such an exhaust purification apparatus can be used not only for the purification of exhaust, but also as an air purifier for homes and vehicles.

[0056] In this case, it is preferred that the intake opening be provided in the lower part of the cabinet, the exhaust release opening be provided in the upper part of the cabinet, and the exhaust path be formed so that the exhaust flows from the bottom to the top inside the cabinet. With such a configuration, the contaminants (oil particles and the like) present in the exhaust are removed in the pretreatment unit provided in the lower part. Therefore, even in the case of leakage of the oil and fat components trapped in the pretreatment unit, those components do not reach the optical treatment unit provided in the upper part. Therefore, adhesion of oil and fat components to the photocatalytic filter can be effectively prevented. Furthermore, another method for preventing the penetration of oil and fat components into the optical treatment unit preferably comprises the steps of partitioning the inside of the cabinet into a plurality of treatment chambers and disposing each structural component (for example, the de-oiling filter, dust collector, and photocatalytic filter) in those treatment chambers.

[0057] Furthermore, the intake opening may be formed in the upper part and the exhaust release opening may be formed in the lower part of the cabinet if the penetration of oil and fat components trapped in the pretreatment unit into the optical treatment unit is completely prevented, for example, by appropriately separating the pretreatment unit and the optical treatment unit. Furthermore, a configuration may be used in which the pretreatment unit and the optical treatment unit aligned horizontally in the lengthwise direction of the cabinet.

[0058] In such an exhaust purification cabinet, the exhaust release opening thereof can be connected to a main duct of a kitchen or other area to thereby connect the exhaust channel formed inside the cabinet to the exhaust channel inside the main duct. An exhaust purification system can be thus composed of one or a plurality of exhaust purification cabinets connected to the main duct. An exhaust purification system can be configured in this way with one or a plurality of exhaust cabinets connected to the main exhaust duct.

[0059] Furthermore, the exhaust purification apparatus in accordance with the present invention can further comprise a cooking device body comprising a cooking unit, an intake opening, an exhaust release opening, and an exhaust path passing from the intake opening to the exhaust release opening. When the pretreatment unit of such an exhaust purification apparatus (cooking device) comprises a de-oiling filter, it is preferred that the de-oiling filter and the photocatalytic filter be disposed with a displacement in the horizontal direction such that the photocatalytic filter be located not directly below the de-oiling filter. Furthermore, the cooking device body may be also a movable cooking table. Providing such a cooking table makes it possible to construct the exhaust purification apparatus in accordance with the present invention as a smokeless cooking device.

[0060] Connecting the exhaust release opening of such a cooking device (cooking device equipped with an exhaust purification apparatus) to the main duct of a kitchen or the like, makes it possible to obtain a cooking system comprising one or a plurality of cooking devices, similarly to the above-described exhaust purification cabinets.

[0061] The present invention will be described herein below in greater detail based on embodiments thereof.

[0062] <First Embodiment: Exhaust Purification Apparatus (1)>

[0063] The First Embodiment relates to the installation of the exhaust purification apparatus in accordance with the present invention in an exhaust duct leading from a kitchen to the outside.

[0064] As shown in **FIG. 1** and **FIG. 2, a** kitchen **105** is partitioned by a structural wall **104** of a building **101**. A door way **103** is formed in the structural wall **104**. A plurality (for example, five) cooking stands **106** are disposed in the kitchen **105**. A range hood **111** is mounted above each cooking stand **106**. One end of an exhaust duct **108** extending to the rooftop exhaust release opening **112** along the outer wall surface of the building **101** is opened in the range hood **111**.

[0065] The exhaust purification apparatus **107** can be said to be generally composed of a pretreatment section **117** provided in connection to one end of the exhaust duct **108**, and an optical treatment section **119** provided in the vicinity of the other end inside the exhaust duct **108**. A fan **114** is provided between the pretreatment section **117** and the optical treatment section **119**. If the fan **114** is operated, the exhaust released from inside of the kitchen **105** flows via the pretreatment section **117**, exhaust duct **108**, and optical treatment section **119** and is released to the outside from the exhaust release opening **112**, as shown by the arrows in **FIG. 1**.

[0066] A de-oiling filter **20** is arranged in the pretreatment unit **117**. The de-oiling filter **20** is a general grease filter and has a capacity of removing no less than 70 wt. % of oil and fat components present in the exhaust.

[0067] The optical treatment unit **119**, as shown in **FIG. 3**, comprises a plurality (two in this case) of photocatalytic units **61** disposed inside the exhaust duct **108**. As shown in **FIG. 4** and **FIG. 5**, each photocatalytic unit **61** comprises a plurality of (for example, twelve) photocatalytic filters **62** and light sources **63** for illuminating those photocatalytic filters **62** with light. The photocatalytic filters **62** are arranged opposite each other so as to sandwich the light sources **63**, and all those components are held integrally in a frame **64**.

[0068] The photocatalytic filter **62**, as shown in **FIG. 6**, is formed to have a planar shape. The photocatalytic filter **62** comprises a ceramic substrate **73** shown in **FIG. 7** and a photocatalytic layer **76** (see **FIG. 8**) covering the surface of the ceramic substrate **73**. The photocatalytic layer **76** contains titanium oxide serving as a photocatalyst as the main component. The ceramic substrate **73**, as shown in **FIG. 7**, comprises a ceramic porous body **71** composed of skeletal sections **77** with three-dimensional net-like structure and a plurality of ceramic particles **72** held on the surface of the porous ceramic body **71**. The ceramic particles **72** held on the surface of the porous ceramic body **71** form peaks and valleys on the surface of the ceramic substrate **73**. Furthermore, for convenience of explanation, in part of **FIG. 7**, ceramic particles **72** are removed to expose the skeletal sections **77** of the porous ceramic body **71**. **FIG. 8** is a cross-sectional view along the VIII-VIII line of the configuration in which the photocatalytic layer **76** was formed on the ceramic substrate **73** shown in **FIG. 7**.

[0069] In the photocatalytic filter **62** used in the present embodiment, alumina particles with a mean diameter of 22 μm are used as the ceramic particles **72**. Furthermore, the mean diameter of the skeletal section **77** of the porous ceramic body **71** is within a range of from no less than 100 μm to no more than 1000 μm. The photocatalytic filter **62** has a porosity within a range of from no less than 65% to no more than 95%, a bulk density within a range of from no less than 0.15 g/cm^3 to no more than 0.60 g/cm^3, and a number of cells within a range of from no less than 10 cells per 25 mm to no more than 30 cells per 25 mm. Furthermore, the light transmissivity of the photocatalytic filter **62** is within a range of from no less than 10% to no more than 50%, when the thickness is 5 mm.

[0070] As shown in **FIG. 4** and **FIG. 5**, the frame **64** is formed to have a box-like shape and is composed from a corrosion-resistant metal such as stainless steel, and a pair of opposing side surfaces thereof are open. Furthermore, a plurality (for example, six) photocatalytic filters **62** are arranged in a row on the same surface, and those filters are held on a lattice-like frame **68**, thereby forming a planar photocatalytic module **69**. Two photocatalytic modules **69** are mounted in the openings provided in the two side surfaces of the frame **64**. A plurality of light sources **63** held in the frame **64** are arranged parallel to each other between those photocatalytic modules **169**. In the photocatalytic unit **61** of such a configuration, the photocatalytic filters **62** are exposed to the outside from the openings in two sides of the frame **64**. The exhaust passes through the photocatalytic unit **61** via the two-layer photocatalytic filter **62**. In the present embodiment, four UV lamps were used as the light sources **63**.

[0071] Instead of arranging the photocatalytic unit **61** in which the photocatalytic filters **62** were integrated with the light sources **63**, the photocatalytic filters **62** and light sources **63** may be arranged as separate components in the exhaust duct **108**, for example, as shown in **FIG. 9**. The light sources **63** can be arranged between the two photocatalytic filters **62**. Furthermore, the light source **63** may be disposed further downstream of the photocatalytic filter **62** which is located in the most downstream location with respect to the flow direction of the exhaust. Furthermore, the light source **63** may be disposed further upstream of the photocatalytic filter **62** which is located in the most upstream location with respect to the flow direction of the exhaust. Those light sources **63** disposed upstream or downstream are preferably provided with reflective plates **79**, on the sides that do not face the photocatalytic filter **62**.

[0072] The operation of the exhaust purification apparatus **107** will be described below.

[0073] As shown in **FIG. 1**, cooking conducted inside the kitchen **105** produces contaminants and odorous components. The exhaust containing those contaminants and odorous components is sucked into the range hood **111** by the operation of fan **114** and passed through the de-oiling filter **20** provided in the pretreatment unit **117**. As a result, no less than 70 wt. % (preferably no less than 90 wt. %, even more preferably no less than 95 wt. %) of the oil and fat components contained in the exhaust are removed.

[**0074**] The exhaust that passes through the pretreatment unit **117** further flows inside the exhaust duct **108** to the optical treatment unit **119** and passes through the photocatalytic filters **62** installed in the photocatalytic unit **61**. In this process, the exhaust traverses a non-linear path so as to weave through the three-dimensional net-like structure of the photocatalytic filter **62**. As a result, a small amount of contaminants remaining in the exhaust is trapped in the photocatalytic filters **62**. Furthermore, odorous components remaining in the exhaust are brought into contact with the photocatalytic layer **76** formed on the surface of the photocatalytic filter **62** by a turbulent flow generated by the passage of the exhaust. Those contaminants and odorous components are photo-decomposed by the photocatalytic action of titanium oxide serving as the main component of the photocatalytic layer **76**.

[**0075**] Thus, if titanium oxide is illuminated with UV radiation emitted from the light sources **63**, moisture (H_2O) that adheres to the surface of the photocatalytic layer **76** or moisture present in the exhaust is oxidized, producing hydroxyl radicals (.OH). At the same time, oxygen is reduced and superoxide ions ($.O_2^-$) are produced. Because those hydroxyl radicals and superoxide ions demonstrate a strong oxidizing effect, the contaminants (in particular, organic compounds) trapped on or brought into contact with the surface of the photocatalytic filter **62** can be decomposed. Therefore, odorous components and fine contaminants present in the exhaust can be decomposed and removed from the exhaust by photocatalytic action. Moreover, the exhaust is converted into pure air and can be released to the outside through the exhaust opening **112**.

[**0076**] <Second Embodiment: Exhaust Purification Test>

[**0077**] Exhaust, generated from a daily dish-cooking site, was purified by using the exhaust purification apparatus **107**, having a structure described in the First Embodiment.

[**0078**] A total of five friers, three small kitchen ranges, and one steamer were disposed in the kitchen **105** shown in **FIG. 1** and **FIG. 2**. Cooking of fried food, dumplings, boiled food, Japanese pickles and preparation of marine products were carried out in the kitchen **105** for 10 h per day. The exhaust from the daily dish-cooking site was purified with the exhaust purification apparatus **107** at a flow rate of the exhaust of 2000 m^3/h and a flow velocity of 0.76 m^2/s.

[**0079**] An AirWonder™ filter manufactured by TotekJapan Co., Ltd. was used as the de-oiling filter **20** employed in the pretreatment unit **117**.

[**0080**] In the photocatalytic unit **61** of the optical treatment unit **119**, as shown in **FIG. 4** and **FIG. 5, a** total of six photocatalytic filters **62** were held in the frame **68** so as to form a configuration with a length of 500 mm, a height of 400 mm, and a thickness of 13 mm. The units were assembled in the frame **64** so as to form two layers with a spacing of 38 mm therebetween in the thickness direction thereof (exhaust flow direction). The photocatalytic unit **61** had the following external dimensions: length 506 mm, height 444 mm, thickness 64 mm. Each photocatalytic unit **61** comprised four UV lamps as power sources **63**. A 6 W black light (manufactured by Noritake Co., Limited, trade name "HL Lamp," wavelength 300-420 nm, peak wavelength 360-380 nm) was used as the UV lamp. A total of three of photocatalytic units **61** were connected in the lateral direction, and two such sets were fabricated and arranged inside the exhaust duct **108** so as to obtain two layers against the flow direction of exhaust.

[**0081**] Exhaust was purified for 1 month and 4 months under the above-described conditions. Then, the concentration of odor in the exhaust discharged from the exhaust release opening of the exhaust duct, was measured with a three-point odorous cloth method by an odor measurement officer. The UV lamps were operated continuously during exhaust purification. The concentration of odor in the exhaust discharged from the exhaust release opening of the exhaust duct before the installation of the exhaust purification apparatus and the concentration of odor in the kitchen refuse collection site where the kitchen refuse discharged from the kitchen was collected were measured in a similar manner for the sake of comparison. The results are shown in Table 7. The relation between the odor index Z and odor concentration Y is represented by the formula Z=10logY.

TABLE 1

Sample No.	Odor concentration Y	Odor concentration Z
Under the range hood (original odor)	550	27
Exhaust release opening (before the installation of the exhaust purification apparatus)	730	29
Exhaust release opening (one month after the installation of the exhaust purification apparatus)	98	20
Exhaust release opening (four months after the installation of the exhaust purification apparatus)	41	16
Kitchen refuse collection site	730	29

[**0082**] As shown in Table 1, the exhaust discharged from the exhaust release opening before the installation of the exhaust purification apparatus had a high odor concentration similarly to the kitchen refuse collection site. The odor concentration in the exhaust is higher than the exhaust odor (original odor) under the range hood apparently because of the effect of contaminants and odorous components that had already adhered inside the exhaust duct. On the other hand, the odor concentration one month after the installation of the exhaust purification apparatus decreased substantially and the exhaust odor could not be sensed at all. This is apparently because the contaminants and odorous components contained in the newly discharged exhaust and the odorous components that have already adhered inside the exhaust duct were almost completely removed by the installed exhaust purification apparatus. Furthermore, four months after the installation of the exhaust purification apparatus, the results obtained were equivalent to or better than those obtained one month after the installation.

TEST EXAMPLE 1

[0083] A filter comprising a ceramic substrate in which ceramic particles were held in a porous ceramic body with a three-dimensional net-like structure and a photocatalyst supported on the ceramic substrate was used as the photocatalytic filter constituting the exhaust purification apparatus of the First Embodiment. Several tests were devised, and the effect produced by the photocatalytic filter composed by using the ceramic substrate of such a shape was studied together with the optimum size of ceramic particles.

[0084] The samples for the tests were fabricated as follows: A total of 446.5 g of fine ceramic powder (fine alumina powder), 16.0 g of talc, 36.5 g of kibushi clay, 155 g of water, and 12.5 g of a dispersant were placed into a pot mill made of polyethylene and having a capacity of 2 L. Furthermore, alumina balls with a diameter of 10 mm were also placed into the pot mill to about ⅓ thereof and the components were stirred and mixed for 5 h. Then, 127.1 g of an organic binder (manufactured by Daiichi Pharmaceuticals Co., Ltd., trade name "Seramo TB-01") was added to the pot mill, and the components were further stirred for 20 h. A slurry for the formation of a porous ceramic body was thus prepared.

[0085] An organic porous body (in this case, planar urethane foam) having a three-dimensional net-like structure was placed into the slurry and impregnated therewith. The urethane foam was then removed from the slurry and the excess slurry was pressed out and removed with a roller.

[0086] Ceramic particles (alumina particles) were then sprinkled over the urethane foam and caused to adhere to the undried slurry. At this time, the alumina particles were sprinkled while the urethane foam was subjected to vibrations. As a result, nonuniform adhesion of the alumina particles was prevented and the excess alumina particles were caused to fall to the rear surface side of the urethane foam.

[0087] The slurry and the urethane foam with the alumina particles adhered thereto were dried for 24 h at a temperature of 70° C. and fired for 1 h at a temperature of 160° C. As a result of firing, the urethane foam was burned out and ceramic substrate was obtained in which the alumina particles were supported on (sintered to) the porous ceramic body with a three-dimensional net-like structure.

[0088] A variety of ceramic substrates were fabricated in the same manner as described hereinabove, except that the mean diameter of alumina particles that were caused to adhere to the undried slurry was changed.

[0089] Those ceramic substrates were impregnated with a photocatalytic slurry and fired at a temperature of 500° C. As a result, a photocatalytic layer covering the front surface of the ceramic substrate was baked to the ceramic substrates. A photocatalytic slurry (manufactured by Ishihara Sangyo K. K., trade name ST-K01) containing silica (20 wt. % based on the slurry) as an inorganic binder and having fine particles of anatase-type titanium oxide (photocatalyst) monodispersed in an aqueous solvent was used as the abovementioned photocatalytic slurry. A variety of samples (photocatalytic filters) were prepared with alumina particles (ceramic particles) of different mean particle sizes constituting the ceramic substrates.

[0090] Samples were then prepared in which a photocatalytic layer was formed on the surface of a porous ceramic body (no alumina particles were supported thereon) in the same manner as described hereinabove, except that no alumina particles were used.

[0091] The weight of the photocatalytic layer supported on the samples was found from the difference between the weight of the ceramic substrate (porous ceramic body in the sample using no alumina particles) and the weight of the sample and the supported amount of the photocatalyst was found by multiplying the result by the content of the photocatalyst. Furthermore, external dimensions (volume) of the samples were measured and the mass of the photocatalyst supported per unit volume of each sample was calculated from the supported amount of the photocatalyst and the volume of the samples.

[0092] Furthermore, the bulk density of the samples was calculated from the volume and mass of each sample. A specific surface area of each sample was measured using the single-point BET (Brunauer-Emmett-Teller) method. Based on those values, the surface area of each sample per unit volume thereof was calculated by the following calculation formula:

(Surface area per 1 cm^3 of sample)=(specific surface area [m^2/g])×(bulk density [g/cm^3]).

[0093] Surface area and the supported amount of the photocatalyst per unit volume are shown in Table 2 for each sample. Each value is the mean of measurements of six samples.

TABLE 2

Mean particle size of alumina particles (μm)	Supported amount of photocatalyst (g/cm^3)	Surface area (m^2/cm^3)
0.8	0.006	0.62
22	0.013	3.73
47	0.013	4.50
102	0.012	4.43
(No alumina particles)	0.006	0.61

[0094] As shown in Table 2, in samples provided with a photocatalytic layer on a ceramic substrate having alumina particles with a mean particle size of no less than 1 μm and no more than 100 μm, the surface area and the supported amount of photocatalyst per unit volume were greatly increased in comparison with those of the sample in which a photocatalytic layer was provided on a ceramic porous body that supported no alumina particles. Furthermore, when the surface of the samples was observed with a scanning electron microscope after the samples were subjected to vibration, it was found that alumina particles fell off in the samples with the mean particle size of alumina particles of more than 100 μm. Furthermore, in samples with a mean particle size of alumina particles supported on a ceramic porous body of less than 1 μm, no increase in the surface area and supported amount of photocatalyst was observed.

TEST EXAMPLE 2

[0095] A photocatalytic slurry (manufactured by Ishihara Sangyo K.K., trade name STS-01) containing no inorganic binder was used instead of the photocatalytic slurry used in Test 1. The concentration of titanium oxide in this photocatalytic slurry was about 30%. Alumina particles with the mean particle size shown in Table 3 were used as the ceramic particles. With respect to other aspects, a variety of samples were formed in the same manner as in Test Example 1. Furthermore, similarly to Test Example 1, a sample was prepared in which a photocatalytic layer was formed on the surface of a ceramic porous body in which no alumina particles were held.

[0096] With respect to those samples, the supported amount of photocatalyst and the surface area were measured in the same manner as in Test Example 1. Furthermore, the surface of the samples was observed in scanning electron microscope after subjecting the samples to vibrations. The results are shown in Table 3. All the values in the table are mean values of the results obtained in measurements conducted for six samples.

TABLE 3

Mean particle size of alumina particles (μm)	Supported amount of photocatalyst (g/cm^3)	Surface area (m^2/cm^3)
8	0.061	25.00
22	0.068	23.08
47	0.065	25.23
No alumina particles	0.011	2.26

[0097] Comparison of Table 2 and Table 3 demonstrates that the samples (Table 3) prepared by using a photocatalytic slurry containing no inorganic binder had more titanium oxide held per unit surface area than the samples (Table 2) prepared by using a photocatalytic slurry containing an inorganic binder. Furthermore, when the mean particle size of alumina particles is within a range of from 8 to 47 μm, the application of vibration was found to cause no separation of alumina particles and peeling of the photocatalytic layer.

TEST EXAMPLE 3

[0098] The relationship between the mean diameter of the skeletal section constituting the ceramic porous body and the compressive strength of the photocatalytic filter was studied.

[0099] A urethane foam with a mesh size of #13 was used as the organic porous body, alumina particles with a mean particle size of 22 μm were used as the ceramic particles, and a slurry manufactured by Ishihara Sangyo K. K. (trade name STS-01) was used as the photocatalytic slurry. A variety of samples with skeletal sections of different mean diameters were prepared by a method similar to that used in Test Example 1. The thickness of the samples was 15 mm. The mean diameter of the skeletal sections was varied by changing the concentration of solids and/or viscosity of photocatalytic slurry used for the preparation of the samples. The diameter of the skeletal sections was measured in 30 locations by observing the samples with an electron microscope, and the mean value calculated from the measurement results was used as the mean diameter of skeletal sections.

[0100] The compressive strength of each sample was measured with a universal testing machine (manufactured by Shimadzu Seisakusho K. K.). The results obtained are shown in Table 4.

TABLE 4

Mean diameter of skeletal sections (μm)	Compressive strength (MPa)
76	0.01
101	0.2
560	0.4
981	0.8
1490	1.5

[0101] Table 4 shows that the compressive strength decreased as the skeletal section became thinner. The samples with a mean skeletal section diameter of less than 100 μm were damaged and broken when held the hand. By contrast, the samples with a mean diameter of skeletal section of no less than 100 μm had a sufficient handling strength.

TEST EXAMPLE 4

[0102] The relationship between the mean diameter of the skeletal sections and pressure loss was studied.

[0103] A pressure loss at the usual flow rate of exhaust inside an exhaust duct in a restaurant or the like was measured for all the samples prepared in Test Example 3. The results are presented in Table 5 and **FIG. 10**.

TABLE 5

Mean diameter of	Pressure loss (mm Aq)		
skeletal sections (μm)	Flow rate 1.5 m/sec	Flow rate 3.0 m/sec	Flow rate 4.5 m/sec
76	1.4	2.6	5.9
101	1.6	2.7	6.1
560	2.5	4.2	7.5
981	3.4	5.9	10.1
1490	8.2	13.7	18.5

[0104] As shown in Table 5 and **FIG. 10**, if the mean diameter of the skeletal sections exceeds 1000 μm, the pressure loss rapidly increases. The results obtained in Test Examples 3 and 4 demonstrate that the mean diameter of skeletal section constituting the ceramic porous body is preferably from no less than 100 μm to no more than 1000 μm.

TEST EXAMPLE 5

[0105] The light transmissivity of the photocatalytic filter was examined.

[0106] A total of eight samples were prepared in the same manner as in Test Example 3. The samples were of two groups with a mean diameter of skeletal section of 891 μm and 1490 μm, each group consisting of four samples with a thickness of 5 mm, 10 mm, 15 mm, and 20 mm.

[0107] The light transmissivity of the samples was measured in the manner as follows. In greater detail, a black light (manufactured by Toshiba Linek Co., Ltd., trade name FL10BLB, wavelength 300-420 nm, peak wavelength 360 nm) was disposed in a position at a distance of 7 cm from the sample surface. A UV intensity meter (manufactured by Minolta Co., Ltd., trade name UM-10) was disposed in contact with the rear surface of the sample, and the intensity of UV light transmitted through the sample was measured. Light transmissivity was calculated according to the equation given below based on the ratio of the results obtained when the sample was arranged between the black light and UV intensity meter to when the sample was not arranged therebetween.

Light transmissivity (%)=[(Measured intensity obtained when the sample was arranged)/(Measured intensity obtained when the sample was not arranged)]×100.

TABLE 6

Thickness of photocatalytic filter (mm)	Light transmissivity (%) Mean diameter of skeletal sections 891 μm	Mean diameter of skeletal sections 1490 μm
20	0.5	0.0
15	2.0	0.0
10	8.4	0.6
5	27.0	8.0

[0108] As shown in Table 6, in the samples with a mean skeletal section diameter exceeding 1000 μm, the light transmissivity was almost 0% when the sample thickness was greater than 10 mm. On the other hand, in the samples with a mean skeletal section diameter of no more than 1000 μm, the light transmissivity at a thickness of 10 mm was 8.4%, and that at a thickness of 5 mm was no less than 25%, indicating satisfactory light transmissivity. These test results relating to light transmissivity also demonstrate that the mean diameter of skeletal section constituting the ceramic porous body is preferably no more than 1000 μm.

[0109] Furthermore, the porosity, bulk density, and the number of cells per length of 25 mm were also measured for those samples. The porosity was measured by a mercury impregnation method, the bulk density was measured in the same manner as in Test Example 1, and the number of cells was measured with an optical microscope.

[0110] As a result, all the samples for which satisfactory test results were obtained satisfied at least one of the following three conditions: (1) porosity is no less than 65% and no more than 95% (more preferably, no less than 75% and no more than 85%), (2) bulk density is no less than 0.159/cm^3 and no more than 0.609/cm^3 (more preferably, no less than 0.189/cm^3 and no more than 0.409/cm^3), and (3) the number of cells is no less than 10 cells per 25 mm and no more than 30 cells per 25 mm (more preferably, no less than 12 cells per 25 mm and no more than 20 cells per 25 mm). Even better results were demonstrated by the samples satisfying two of those conditions, and still better results were demonstrated by the samples for which all the above-described conditions were satisfied.

TEST EXAMPLE 6

[0111] The ability of the filter to decompose acetaldehyde decomposition was examined.

[0112] A sample with a height of 50 mm, a length of 50 mm, and a thickness of 10 mm was hung so that the plan-view surface (50 mm×50 mm surface) of the sample was vertical inside a container (manufactured by PYLEX Co.) having a capacity of 0.0013 m^3 (1.3 L) and equipped with a stirring element. This container was equipped with a stirring element creating a flow of gas inside the container. A black light was installed below the container, and the plan-view surface of the sample was illuminated with UV light at 1 mW/cm^2 and a wavelength of 360 nm.

[0113] A sample (sample 1) prepared by forming a photocatalytic layer on a ceramic substrate supporting alumina particles with a mean diameter of 22 μm and a sample (sample 2) prepared by forming a photocatalytic layer on a ceramic substrate which supported no alumina particles were used as the samples. A photocatalytic slurry identical to that used in Test Example 2 was employed for forming the photocatalytic layer.

[0114] Acetaldehyde (purity 90%, saturated state at 23°) was injected into the container in an amount of 0.2 mL 0 min (when the black light was turned on), 20 min, 40 min, 60 min, and 80 min after the black light was turned on, while the stirring element was rotated to create gas flow inside the container. The black light was turned off 58 min after it was turned on. After the prescribed intervals from the time the black light was turned on had passed, gas present inside the container was sampled and quantitatively analyzed by gas chromatography. The results are shown in Table 7 and **FIG. 11**.

TABLE 7

Time (min)	Acetaldehyde concentration (ppm) Sample 1	Sample 2	No sample
0	107	107	107
1	26	62	102
10	0	12	99
20	0	0	96
Injection	107	107	203
21	22	61	198
30	0	10	195
40	0	0	193
Injection	107	107	300
41	25	60	296
50	0	11	293
60	0	0	291
Injection	107	107	398
61	21	62	395
70	1	16	392
80	1	5	388
Injection	108	107	495
81	23	68	490
90	2	19	485
100	1	10	482

[0115] As shown in Table 7 and **FIG. 11**, in a blank test in which illumination with black light was conducted without placing a sample into the container, the concentration of acetaldehyde inside the container showed practically no decrease, accumulating upon each injection. This result indicates that UV irradiation alone practically fails to decompose acetaldehyde. By contrast, in the test utilizing sample 2 (photocatalytic filter which was not equipped with alumina particles) the concentration of acetaldehyde decreased to about 3/5 of the initial concentration within 1 min after the introduction of acetaldehyde into the container, and after 20 min from the introduction, practically no acetaldehyde was detected. Furthermore, in the test utilizing sample 1 (photocatalytic filter comprising alumina particles), the concentration of acetaldehyde decreased to about 1/4 of the initial concentration within 1 min after the acetaldehyde was introduced and practically no acetaldehyde was detected (i.e., it had completely decomposed) after 10 min. Those results indicate that under the above-described test conditions, both sample 1 and sample 2 almost completely decompose 0.2 mL acetaldehyde by photocatalytic action within 20 min. Furthermore, sample 1 comprising a photocatalytic layer on a ceramic substrate holding alumina particles exhibited decomposition ability even better than that of sample 2.

[**0116**] <Third Embodiment: Exhaust Purification Cabinet>

[**0117**] An embodiment (exhaust purification cabinet) in which the exhaust purification apparatus in accordance with the present invention comprises a cabinet will be described herein below with reference to **FIGS. 12 through 14**. Parts operating similarly to parts described in the First Embodiment are assigned the same reference symbols, and explanation thereof will be omitted.

[**0118**] The present exhaust purification apparatus comprises de-oiling filters **80**, **81** for removing oil and fat components, a dust collector **50** for removing smoke particles, a photocatalytic unit **61** for deodorization, and a fan **207** for sucking the exhaust into the cabinet **203** and releasing it after purification, all those components being installed inside the cabinet **203** having an intake opening **201** and an exhaust release opening **202** formed therein. The structure of the photocatalytic unit **61** is similar to that described in the First Embodiment.

[**0119**] The cabinet **203** is formed to have an elongated box-like shape and has a caster **208** for transportation attached to the bottom surface thereof. The intake openings **201** are formed at the central portions in the lower parts on the two opposing side surfaces of the cabinet **203**. The intake openings **201** are in the form of round holes. The exhaust release openings **202** are formed in the upper portions of the same side surfaces where the intake openings **201** were formed. The exhaust release openings **202** are in the form of a plurality of slits. The exhaust release openings **202** may be provided not only on the two side surfaces of the cabinet **203**, but also on three or four side surfaces. Furthermore, they may be also formed at the upper surface of the cabinet **203**. Alternatively, an exhaust release opening may be formed only on one side surface and upper surface.

[**0120**] The internal space of the cabinet **203** is divided into 4 chambers stacked in layered configuration. The intake openings **201** are provided in the lowermost-layer chamber **210**, which is the lowermost chamber. A first treatment chamber **211** with the de-oiling filters **80**, **81** disposed therein, a second treatment chamber **212** with the dust collector **50** disposed therein, and a third treatment chamber **213** with the photocatalytic unit **61** and the fan **207** disposed therein are arranged in the order of description above the lowermost-layer chamber **210**. As shown in **FIG. 12**, an orifice **214** leading to the first treatment chamber **211** is formed in an edge of the upper surface of the lowermost chamber **210**. An orifice **215** leading to the second treatment chamber **212** is formed at an edge (on the right side as shown in **FIG. 12**) of the upper surface of the first treatment chamber **211**. An orifice **216** leading to the third treatment chamber **213** is formed at another edge (on the side opposite that of the orifices **214**, **215**; on the left side as shown in **FIG. 12**) of the upper surface of the second treatment chamber **212**. The exhaust release openings **202** are provided in the third treatment chamber **213**. As a result, an exhaust path passing from the intake opening **201** to the exhaust release opening **202** via the lowermost-layer chamber **210**, the first treatment chamber **211**, the second treatment chamber **212**, and the third treatment chamber **213** is formed inside the cabinet **203**. The exhaust sucked in through the intake opening **201** flows as shown by arrows in **FIG. 12** and **FIG. 13** along the exhaust path.

[**0121**] The first treatment chamber **211** is divided into two layers (upper layer and lower layer) by a partition board **218** having an orifice **217** in the other edge (side opposite to that of the orifices **214**, **215**). The exhaust that flows from the orifice **214** into the first treatment chamber **211** flows from one side to the other end side along the lower layer of the first treatment chamber, through the orifice **218**, and then from the other side to the first side in the upper layer to the orifice **215**. Planar de-oiling filters **80**, **81** are arranged with a certain spacing therebetween in the portion where the exhaust is curved. Thus, one de-oiling filter **80** is mounted in a state inclined with respect to the flow direction so as to cross the exhaust path, wherein the other de-oiling filter **81** is mounted above it in a state inclined in the direction opposite to that of the de-oiling filter **80**. When the de-oiling filters **80**, **81** are thus inclined, the contact surface area of the de-oiling filters **80**, **81** with the exhaust can be increased and a larger amount of contaminating substances can be trapped. The de-oiling filters **80**, **81** are typical grease filters and the oil removal efficiency of those de-oiling filters **80**, **81** is no less than 70 wt. %. Furthermore, three or more de-oiling filters may be arranged in this zone.

[**0122**] The dust collector **50** is an electric dust collector with a structure in which discharge electrodes **51** and dust collection electrodes **52** are arranged and installed alternately and parallel to the exhaust flow direction in a dust collection case **53**. When a high voltage is applied to the discharge electrodes **51**, a corona discharge is generated, and negative ions and electrons are generated from the discharge electrodes. When particles such as smoke or mist collide with those ions and electrons, the particles are charged. The charged particles are electrostatically attracted to the dust collection electrodes **52**. As a result, particles (smoke particles and the like) present in the exhaust are separated and removed.

[**0123**] Two dust collectors **50** are detachably mounted in series in the exhaust path inside the second treatment chamber **212**. Here, the cross-sectional area in the second treatment chamber **212** is larger than the cross-sectional area of the exhaust path in the first treatment chamber **211**. Therefore, the flow rate of exhaust is slower in the second treatment chamber **212** than in the first treatment chamber **211**. The dust collectors **50** trap particles by electrostatically attracting the charged particles. Therefore, if the movement speed of the charged particles is higher than the attraction speed, the particles pass through without being attracted to the dust collection electrodes **52**. Increasing the cross-sectional area of the second treatment chamber **212** over that of the first treatment chamber **211**, as in the present embodiment, makes it possible to pass the exhaust at a relatively low speed through the dust collector **50**, thereby increasing the particle removal efficiency.

[**0124**] As shown in **FIG. 13**, the photocatalytic unit **61** is disposed so as to cover the exhaust release opening **202** formed in the side wall of the third treatment chamber **213**. The third treatment chamber **213** has a volume larger than that of other treatment chambers. Furthermore, the fan **207** is disposed in the third treatment chamber **213**. As shown in **FIG. 12**, the fan **207** is disposed so as to cover the orifice **216** connecting the second treatment chamber **212** and the third treatment chamber **213**. Exhaust sucked in through the second treatment chamber **212** is released, so as to be dispersed inside the third treatment chamber **213** by the fan **207** (see **FIG. 13**). Because the exhaust is thus caused to diffuse inside the third treatment chamber **213**, the exhaust passes through the exhaust path with a larger cross-sectional area. As a result, the flow rate of exhaust is decreased. Therefore, the time of contact between the exhaust and the photocatalytic filter **61** is extended and a better deodorization effect can be obtained. Because the photocatalytic unit **61** is disposed in the uppermost layer of cabinet **203**, the oil and fat components present in the exhaust do not reach the unit. Therefore, the adhesion of oil and fat components to the photocatalytic filter **62** and a drop in the function thereof can be prevented.

[**0125**] The operation of the exhaust purification cabinet will be described below. First, the cabinet **203** comprising the exhaust purification apparatus is moved into the kitchen. Exhaust generated by cooking (including contaminating substances such as oil particles and smoke particles and also odorous components) is sucked through the inlet opening **201** into the cabinet **203** by the suction force generated by the fan **207**. The exhaust that was sucked in passes from the lowermost-layer chamber **210** into the first treatment chamber **211**, as shown in **FIG. 12**, and then passes through the de-oiling filters **80, 81**. As a result, no less than 70 wt. % of oil and fat components present in the exhaust are removed.

[**0126**] The de-oiling filters **80, 81** are suitable for removing components (oil and fat components and the like) with a comparatively large mass among the contaminating substances. On the other hand, part of fine contaminating substances such as smoke particles and most of the gaseous odorous components pass through the de-oiling filters **80, 81**. Exhaust containing those components flows from the first treatment chamber **211** into the second treatment chamber **212**. When the exhaust enters the second treatment chamber **212**, because the cross-sectional area of the exhaust path increases, the exhaust reaches the dust collector **50** in a state in which the flow velocity thereof is reduced. When the exhaust passes through the dust collector **50**, particles, such as smoke, present therein are charged electrically and attracted to the dust collection electrodes **52**. As a result, smoke and mist particles present in the exhaust are removed.

[**0127**] The exhaust treated in the second treatment chamber **212** is sucked into the third treatment chamber **213** and, as shown in **FIG. 13**, diffused and dispersed inside this chamber with the fan **207**. The exhaust filling the third treatment chamber **213** is brought into uniform contact with the photocatalytic unit **61**, passes therethrough and is released from the exhaust release opening **202** to the outside of the cabinet **203**. At this time, the contaminating substances that could not be removed by the dust collector **50** and the odorous components present in the exhaust are brought into contact with or trapped by the surface of the photocatalytic filter **62**. Those odorous components and fine particles are decomposed by photocatalytic action.

[**0128**] As the cabinet is used, oil and fats trapped by the filters **80, 81** can start dripping or flowing along the de-oiling filters **80, 81** in the exhaust purification cabinet of the above-described configuration. For this reason, it is preferred that an oil receptacle be provided below the de-oiling filter **80**. Furthermore, even when oil and fats fall drop-wise from the de-oiling filters **80, 81**, because the exhaust path is formed so that the upper part of the cabinet **203** is located downstream, the downstream exhaust path cannot be contaminated by the dripping oils and fats.

[**0129**] Furthermore, a cleaning means for cleaning the de-oiling filters **80, 81** may be also provided. For example, a nozzle for ejecting a cleaning solution can be provided above the de-oiling filters **80, 81** and a solution receptacle can be installed below the filters. With such a configuration, spraying the cleaning solution from the nozzle onto the de-oiling filters **80, 81** makes it possible to wash out the oil and fat components trapped in the de-oiling filters **80, 81**. Furthermore, the performance of the de-oiling filters **80, 81** can be maintained for a long time and maintenance frequency can be reduced.

[**0130**] The de-oiling filters **80, 81**, dust collector **50**, and photocatalytic unit **61** are mounted inside the cabinet **203**, and each of them can be easily attached and detached. Thus, when the contaminating substances removed from the exhaust in the course of the exhaust purification process have accumulated, those units can be removed from the cabinet **203** and cleaned or replaced with new products.

[**0131**] <Fourth Embodiment: Cooking Device Equipped with the Exhaust Purification Apparatus>

[**0132**] An embodiment in which the exhaust purification apparatus in accordance with the present invention comprises a cooking device body (cooking device equipped with the exhaust purification apparatus) is shown in **FIG. 15**. A so-called smokeless roaster of a well-known structure can be used as the cooking device body. A central orifice is provided in a ceiling plate **301***a* of a cooking device body **301**, and a cooking unit comprising a heater **302** and a cooking plate **303** is fit into the orifice. A gas, heater, electric heater, coal heater, or electromagnetic induction heater may be used as the heater **302**. A roaster, grill, iron plate, or non-conductive plate can be used as the cooking plate **303**.

[**0133**] An exhaust purification apparatus for conducting purification (de-oiling, defuming, and deodorizing) of the exhaust generated from the cooking unit is installed in the cooking device body **301**. The exhaust purification apparatus comprises a de-oiling filter **20** for removing oils and fats contained in the exhaust that was sucked in, a dust collector **50** for removing smoke particles, a photocatalytic unit **61** for deodorizing, and a fan **307** for sucking in the exhaust and releasing it after purification. The configuration of the de-oiling filter **20** and the photocatalytic unit **61** are similar to those of the first Embodiment, and the configuration of the dust collector **50** is similar to that of the Third Embodiment.

[**0134**] The heater **302** and cooking plate **303** are detachably mounted in an inner box **308**. The inner box **308** is installed inside an outer box **309**. The outer box **309** is fixed to the cooking unit body **301**. An intake plate **310** is attached on the outer periphery of the central orifice in the ceiling plate **301***a*, and an intake opening **311** is formed between the intake place **310** and the upper outer periphery of the inner box **308**. A gap is formed between the inner box **308** and the outer box **309** so as to surround the inner box **308**, and the intake opening **311** leads to this gap. An exhaust release opening **312** is formed in the lower portion of at least one side surface of four side surfaces of the cooking device body **301**.

[**0135**] The de-oiling filter **20** is disposed at the side of the outer box **309**, the dust collector **50** and the fan **307** are disposed below the outer box **309**, and the photocatalytic unit **61** is disposed so as to face the exhaust release opening **312** (to cover the exhaust release opening **312**). Furthermore, an exhaust path passing from the intake opening **311** through the de-oiling filter **20**, dust collector **50**, and photocatalytic unit **61** to the exhaust release opening **312** is formed inside the cooking device body **301**. Furthermore, the gap formed between the inner box **308** and the outer box **309** also becomes part of the exhaust path. Exhaust (containing oil and fat components, smoke particles, odorous components and the like) generated from the cooked food during heating and cooking in the cooking unit is sucked into the exhaust path from the intake opening **311** by the suction force generated by the fan **307** as shown by the arrows in the drawing. This exhaust flows sidewise along the outer surface of the inner box **308** and downward from the side of the outer box **309** through the de-oiling filter **20**. Then, it flows through the dust collector **50** and photocatalytic filter **61** and is released to the outside through the exhaust release opening **312**.

[**0136**] The area where the de-oiling filter **20** was installed is a portion where the exhaust path is a portion curved downwardly from the side of the outer box **309**. Furthermore, the exhaust path leading to the de-oiling filter **20** is formed between the side surface of the cooking device body **301** and the outer box **309**. Therefore, it has a small cross-sectional area. For this reason, the flow velocity of the exhaust passing through this portion is comparatively high.

[**0137**] On the other hand, the dust collector **50** is detachably attached inside the exhaust path below the outer box **309**. The exhaust path from the filter unit **10** to the dust collector **50** expands in the horizontal direction below the cooking unit. The cross-sectional area of the exhaust path in this portion can be larger than that of the exhaust path in the portion leading to the de-oiling filter **20**. As a result, the flow velocity of the exhaust can be reduced by comparison with that in the zone upstream of the de-oiling filter. Appropriately decreasing the flow velocity of the exhaust makes it possible to efficiently separate and remove smoke particles present in the exhaust with the dust collector **50** disposed herein.

[**0138**] The photocatalytic unit **61** is disposed so as to cover the exhaust release opening **312** formed in the side surface of the cooking device body **301**, and the photocatalytic filter **62** faces the exhaust release opening **312**. The exhaust path where the photocatalytic unit **61** is disposed is in the lower portion inside the cooking device body **301**. Therefore, a large space can be easily provided. The exhaust sucked in herein is released, so as to be dispersed by the fan **307** to all four sides inside the cooking device body **301**. As a result, the flow velocity of the exhaust can be further decreased and odorous components, present in the exhaust, can be efficiently removed by the photocatalytic filter **62**, similar to the Third Embodiment.

[**0139**] <Fifth Embodiment: Cooking System (1)>

[**0140**] The present embodiment relates to a cooking system having connected therein a plurality of cooking devices equipped with the exhaust purification apparatus in accordance with the present invention. A cooking device used in this embodiment is shown in **FIG. 16**. This cooking device has a configuration similar to that of the cooking device of the Fourth Embodiment; the difference between the two is described below.

[**0141**] The de-oiling filter **20** is disposed below the outer box **309**. The dust collector **50** and the photocatalytic unit **61** are disposed one above the other at the side of the de-oiling filter. Exhaust generated from the cooking unit flows from the side surface of the inner box **308** along the lower surface toward the de-oiling filter **20** located below the inner box **308**. The exhaust path in this portion is formed so as to become narrower toward the de-oiling filter **20**, thereby increasing the flow velocity of the exhaust. In the present embodiment, the photocatalytic units **61** are installed in two layers with respect to the flow direction of the exhaust. As a result, the contact surface area of the exhaust and the photocatalyst is increased and purification efficiency is enhanced. No fan is installed inside the cooking device.

[**0142**] A duct **370** is connected to the exhaust release opening **312** provided in the bottom surface of the cooking device body **301**. The exhaust release opening **312** of the cooking device body **310** is connected to the main duct (not shown in the figure) via the duct **370**. With such a configuration, the exhaust channel formed inside the cooking device body **301** and the exhaust channel inside the main duct are connected to each other. Furthermore, due to the operation of a large fan (not shown in the figures) provided in the main duct, exhaust is sucked in from the intake opening **311** of the cooking devices, purified in the process of flowing toward the exhaust release opening **312**, and sucked into the main duct from the duct **370**.

[**0143**] A valve is provided in the duct **370** of each cooking device. The valves of unused cooking devices are closed, and the suction force generated by the large fan installed in the main duct can be used effectively by opening only the valves of those cooking devices, which are being used. As a result, the suction capacity of exhaust is increased. Furthermore, the purification capacity of exhaust can be also increased.

[**0144**] <Sixth Embodiment: Cooking System (2)>

[**0145**] The present embodiment relates to another example of a cooking system having connected therein a plurality of cooking devices equipped with the exhaust purification apparatus in accordance with the present invention. A cooking device used in this embodiment is shown in **FIG. 17**. In the present embodiment, instead of installing the de-oiling filter **20** used in the Fifth Embodiment, two planar filters **80**, **81** are disposed in the exhaust path with a certain spacing therebetween. Filters **81**, **81** similar to those of the Third Embodiment were used. Similarly to the Fourth Embodiment, the filters **80**, **81** are disposed at the side of the outer box **309**, and the dust collector **50** is disposed below the outer box **309**. Furthermore, the cross-sectional area of the exhaust path from the dust collector **50** to the duct **370** is increased and a plurality (two in this case) of photocatalytic units **61** are aligned horizontally. The configuration of the other components is similar to that of the Fifth Embodiment.

[0146] Similarly to the Third Embodiment, the filters **80**, **81** are disposed in the portion wherein the exhaust path is curved downwardly from the side of the outer box **309**. However, unlike the Third Embodiment, in the present embodiment, exhaust flows from above to below the filters **80**, **81**. Furthermore, a recess **84** is formed on the lower surface of the exhaust path where the filter **81**, which is located lower than the other filter, is disposed. This recess **84** functions as an oil receptacle when oils and fats trapped by the filters **80**, **81** drip down or flow down along the filters **80**, **81**. As a result, contamination of the downstream side of exhaust path with oil and fat components is prevented. Similarly to the Third Embodiment, this cooking device can be further provided with a cleaning means for cleaning the filters **80**, **81**.

[0147] Furthermore, a flow dividing plate may be provided upstream (for example, in the central zone) of the photocatalytic unit **61**. As a result, the exhaust can be guided to both sides of the photocatalytic unit **61**, and the horizontally aligned photocatalytic units **61** (over a large area) can be utilized effectively.

[0148] The present invention was described hereinabove based on specific examples thereof, which however place no limitation on the scope of the claims. The above-described specific examples can be variously changed and modified within the framework of the technology described in the claims.

[0149] Furthermore, technological features explained in the present specification or appended drawings demonstrate the technological utility thereof individually or in a variety of combinations and are not limited to the combination in the description requested at the time of filing of the application. Moreover, the technology described as an example in the present specification or appended drawings attains a plurality of objects at the same time, and attaining one of those objects has by itself technological utility.

What is claimed is:

1. An exhaust purification apparatus disposed in an exhaust channel, comprising

a pretreatment unit for trapping contaminants present in exhaust, and

an optical treatment unit having a photocatalytic filter, wherein

said optical treatment unit is disposed downstream of said pretreatment unit.

2. The exhaust purification apparatus as described in claim 1, wherein

said photocatalytic filter comprises a ceramic substrate and a photocatalyst supported on said ceramic substrate,

said ceramic substrate comprises a ceramic porous body having a three-dimensional net-like structure and ceramic particles held in said ceramic porous body, and

the mean particle size of said ceramic particles is from no less than 1 μm to no more than 100 μm.

3. The exhaust purification apparatus as described in claim 2, wherein the mean diameter of skeletal sections of said ceramic porous body is from no less than 100 μm to no more than 1000 μm.

4. The exhaust purification apparatus as described in claim 3, wherein said photocatalytic filter satisfies at least one of the following three conditions:

(1) a porosity of from no less than 65% to no more than 95%;

(2) a bulk density of from no less than 0.15 g/cm^3 to no more than 0.60 g/cm^3; and

(3) a number of cells of from no less than 10 cells per 25 mm to no more than 30 cells per 25 mm.

5. The exhaust purification apparatus as described in claim 1, wherein said pretreatment unit comprises a particulate filter for trapping particles present in the exhaust.

6. The exhaust purification apparatus as described in claim 1, wherein said pretreatment unit comprises a dust collector for trapping smoke particles present in the exhaust.

7. The exhaust purification apparatus as described in claim 1, wherein said pretreatment unit comprises a de-oiling filter for trapping oil and fat components present in the exhaust.

8. The exhaust purification apparatus as described in claim 7, wherein said de-oiling filter has a capacity of removing no less than 70 wt. % of oil and fat components present in the exhaust.

9. The exhaust purification apparatus as described in claim 7, wherein said de-oiling filter is a multi-layer plate-like filter.

10. The exhaust purification apparatus as described in claim 1, wherein

said pretreatment unit comprises a de-oiling filter for trapping oil and fat components present in the exhaust and a dust collector for trapping smoke particles present in the exhaust, and

said dust collector is disposed downstream of said de-oiling filter.

11. The exhaust purification apparatus as described in claim 10, wherein the sectional area of the opening of said exhaust channel at each flow inlet side of the zone where said de-oiling filter, dust collector, and photocatalytic filter are located increases in the order of description.

12. The exhaust purification apparatus as described in any one claim from claims **1** through **11**, which is further provided with a cabinet comprising an intake opening, an exhaust release opening, and an exhaust path from said intake opening to said exhaust release opening.

13. The exhaust purification apparatus as described in any one claim from claims **1** through **11**, which is further provided with a cooking device body comprising a cooking unit for heating and cooking the product which is to be cooked, an intake opening for sucking in the exhaust from said cooking unit, an exhaust release opening for releasing exhaust that has been purified, and an exhaust path passing from said intake opening to said exhaust release opening.

14. The exhaust purification apparatus as described in any one claim from claims **1** through **11**, wherein said optical treatment unit further comprises a light source for illuminating said photocatalytic filter with light.

15. The exhaust purification apparatus as described in any one claim from claims **1** through **11**, which further comprises a means for supplying ozone that supplies ozone into said exhaust channel.

16. An exhaust purification cabinet containing the exhaust purification apparatus described in any one claim from claims **1** through **11** in a cabinet comprising an intake opening, an exhaust release opening, and an exhaust path from said intake opening to said exhaust release opening.

17. A cooking device containing the exhaust purification apparatus described in any one claim from claims **1** through **11** in a cooking device body comprising a cooking unit for heating and cooking the product which is to be cooked, an intake opening for sucking in the exhaust generated from said cooking unit, an exhaust release opening for releasing exhaust that has been purified, and an exhaust path passing from said intake opening to said exhaust release opening.

18. A cooking system comprising a plurality of the cooking devices described in claim 17 and a main duct connected to the exhaust release opening of each cooking device.

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