

SPECIFICATION

Discharged from Internal
Method and Apparatus for Cleaning Exhaust Gas ~~and~~
or External Combustion Engine
~~Reducing Noise~~ by Using High Voltage Electric Field

5

Technical Field

The present invention relates to a method and an
10 apparatus to clean exhaust gas conveying through the
chamber, by burning up granular particles under plasma
atmosphere, by removing ^{chemical} gaseous materials with negative
ions, and by eliminating NOx with ultraviolet rays,
which are induced by high voltage electric field.

15 Specifically, the present invention relates to a method
and an apparatus which can clean exhaust gas and reduce
noise, wherein it comprises the step of burning up the
granular particles with corona discharge after changing
particles into plasma ^{state} ~~atmosphere~~, the step of removing
20 gaseous materials with negative ions, the step of
eliminating NOx with ultraviolet rays, and the step of
reducing noise.

The main causes of circumstance pollution are smoke and
25 noise produced by industrial equipments and

automobiles.

by virtue of

Especially, diesel engines are used in popular, ~~since~~
~~their~~ low cost
~~it has~~ high power and ~~cost of diesel is low~~.

By the

way, in the event of using diesel engines, there occur

5 some problems that diesel engines push out smoke
including granular particles, hydrocarbons, NOx,
noise and so on, which must be solved to prevent the
circumstance pollution.

In order to solve these problems, intensive studies
10 have been carried about cleaning exhaust gas and
reducing noise.

Background of Art

15 Heretofore known methods make use of catalytic filters,
electric field and recombustion of exhaust gas.

In DE 3834920, the system has been described, wherein
it burns up the deposited carbon particles in ceramic
20 filter with ozone produced by electric field of 20KHz
and 20MV.

In WO 9200442, method and device have been described,
wherein exhaust gases are taken into a channel of
25 ceramic body where an electric field is generated

of
across the direction ^Λ flow, and the soot particles
deposited on the walls of the channel are first
negatively charged by a discharge electrode and then
oxidized by ions adhering to oxygen.

5

In DE 3314168, the system has been described, wherein
neutral particles are divided into two side streams
which are directed over electrodes of large surface
area, held at opposite potentials.

10

In DE 3711312, the method and apparatus have been
described, wherein particles are removed by being
ionized with UV rays and by being collected to the
plate.

15

In US 5074112, an apparatus has been described, wherein
a filter disposed within the cavity removes particulate
products of combustion from exhaust gases passing the
cavity and electromagnetic waves produce heat for
incinerating particulate products of combustion.

20

described conventional methods
As ~~shown in the~~ above, ~~one method~~ can be applied to
eliminate only a kind of ~~ingredient~~ ^{soot particle}, and so the other
ingredients including NOx and noise are pushed out
without eliminating.

25

Accordingly, the inventors of the present invention invented a method and apparatus for cleaning exhaust gas as well as reducing engine noise.

5

SUMMARY OF THE INVENTION

An object of this invention is to provide a method and an apparatus for cleaning exhaust gas pushed out from engines or industrial equipments and reduce engine
10 noises.

Specifically, the object of the present invention is to provide method and apparatus which can clean exhaust gas and reduce engine noise, by partitioning the granular particles and noxious materials in exhaust
15 gas, and then by burning up directly the granular particles under plasma atmosphere, by burning up again the minute particles by means of DC ^{high} voltage and AC ^{high} voltage, by removing noxious materials with negative ions, by removing NO_x by oxidizing it into NO₂ with
20 ultraviolet rays and ozone, which can be easily solved in water which is produced by Sellen's effect of PN diode in this apparatus, and by cutting off engine noises and electromagnetic interference.

25 The apparatus in the present invention is divided into

seven units in order to enhance productivity and efficiency of after-service, which can be used in according to the kind of exhaust gas combination or in separation, since it has an exhaust gas reducing effect in each unit.

5 In this invention, partition unit(~~100~~) renders exhaust gas to pass through at high speed and burns up particles which has been collected in partition unit(~~100~~)

In partition unit(~~100~~), to pass exhaust gas at high
10 speed, EHD(electro-hydro dynamics) method and electrostatic method are applied at bottle necked nozzle to accelerate the flow of exhaust gas.

The negatively charged particles accelerate, much more by voltage difference between ionpin(~~110~~) and attractor
15 electrode(~~120~~), and therefore staying or slowing down of exhaust gas in a chamber is prevented.

The negatively charged particles are attracted by electrostatic force on the collector electrode(~~130~~) which is made of a metal mesh(~~211~~) and particles which
20 can not pass through the collector electrode(~~130~~) of a metal mesh(~~211~~) drop down into the manhole where one set of discharge pole(~~140, 140~~) are disposed to burn up large particles.

In plasma unit(~~200~~), particles passed through collector
25 electrode(~~130~~) are burned by using corona process,

- wherein small particles are burned by streamer corona generated between plasma unit pole (210) and mesh (211). In order to clean exhaust gas more efficiently, exhaust gas is conveyed to electron unit (300) after passing through plasma unit (200). Electron unit (300) burns up minute particles by means of DC ^{high} voltage and AC ^{high} voltage. AC high voltage is applied across pole plate (350) and hole plate (310) in order to generate streamer corona to burn up minute particles.
- 10 DC high voltage is applied across hole plate (310) and ionpin plate (320) ~~to generate electric wind by ionpin (110)~~ which pushes particles to hole plate (350) in order to enhance the efficiency of corona discharge between hole plate (310) and pole plate (350).
- 15 By the above-mentioned process, granular ingredients of exhaust gas are nearly cleared.
- Also, there are noxious chemical materials including NOx in exhaust gas, which are removed with negative ions generated by ionization unit (400) which generates
- 20 UV rays between plasma jet and opposite electrode (430), and this UV rays generate lots of negative ions. Noxious materials combine with negative ions and ozones to be changed into other materials.
- In order to remove NOx which is not removed in the
- 25 above-mentioned ionization unit (400), screen unit (600)

is used.

The screen unit ~~(600)~~ comprises ^{first} ceramic plate A ~~(630)~~,
^{second} ~~ceramic plate C (650)~~ and ceramic plate B ~~(640)~~ having
hexagonal holes (610) in which PN ^{diodes} ~~diode (620)~~ are
5 disposed.

By action of 10K voltage applied across plates, UV rays
are generated around hexagonal hole ~~(610)~~ in a large
amount, and this UV rays let O₂ to be changed into
ozone. In addition, PN diodes ~~(620)~~ cause temperature
10 dropping by Sellen's effect to condensate ^{gaseous} H₂O into
water.

During above process, the efficiency of removing NOx
will be enhanced by taking air into plates.

This invention can contain a union unit ~~(700)~~, which
15 absorbs engine noises and shields electromagnetic wave
to be radiated by high frequency. Union unit is used
to meet the regulations of EMI, EMC specification of
this inventive apparatus.

According to the above, this invention can clear
20 exhaust gas and can be substituted for a noise
absorber.

Brief Description of the Drawings

25 This object, and other objects and advantages of the

Fig. 3(b) is a perspective view of a nozzle mounted on a partition unit guide assembly;

Fig. 4(c) is a perspective view of a plasma unit pole mounted in the inner space of a connecting cap of a plasma unit cell;

present invention, will appear more clearly from the following specification in conjunction with accompanying schematic drawing, in which:

5 FIG.1 is an exploded view ^{of entire components} of the inventive apparatus ;and

FIG.2(a) is a schematic view showing the ~~working~~ ^{cleaning exhaust gas in} principle of ^a partition unit ;and ^{discharging type of a}

FIG.2(b) illustrates a brush corona discharge ;and

10 FIG.3 ^{(a) assembling components} is an ^a embodiment of a partition unit ;and

FIG.4(a) is a ^{perspective} ~~schematic~~ view showing the disposition of ^a

plasma unit cell ~~and opposite electrode~~ ;and ^{discharging type of}

FIG.4(b) ~~is~~ illustrates a ^a streamer corona discharge ^{in a} ~~through hemispheric plasma unit pole~~ ;and ^{cell}

15 FIG.5(a) is ^{an exploded perspective} ~~a detailed view of one set in an electron~~ unit ;and

FIG.5(b) is a schematic view to calculate the distance ^{high voltage electrodes} between ^a ~~dust collector~~ at soot clean-up space

;and

20 FIG.5(c) ^{and FIG. 5(d) are} ~~is~~ a circuit to supply DC ^{high} voltage ^{to an ion pin} ;and

FIG.5(d) ~~is a circuit to supply DC voltage~~ ;and

^{a schematic cross-sectional view of an ionization cell illustrating} FIG.6 is ^a ~~an embodiment of the plasma jet to generate a~~ ^{a generating type of plasma jet;} ~~negative ion~~

^{a perspective view of a plurality of ionization cells mounted} FIG.7 is ^a ~~an ionization cell~~ mounted on a cell-plate

25 ;and

FIG.8 is a detailed view ^{showing one of the assembling type of} ~~to show a screen unit; and~~

FIG.9(a) is a circuit of high-frequency ^{high} voltage generator ;and-

FIG.9(b) ^a is voltage multiplier circuit to multiply voltage applied across a thirdly order coil ;and-

FIG.10 ^{is a horizontal sectional view of a union unit; and} ~~shows an external view of this invention~~

~~apparatus-~~

> FIG. 11 is an external perspective view of the whole apparatus according to the present invention.

Detailed Description of the Preferred Embodiment

10

In the following, the present invention will be explained in detail referring to the drawings.

Referring to Fig.1, which shows the entire ^{components of the apparatus} ~~prospect of~~ for cleaning exhaust gas according to the present invention, ~~the apparatus the present invention, the present invention comprises~~

15 a partition unit(100) which renders exhaust gas to pass through at high speed and burns up large particles which have been collected in a partition unit(100), a plasma unit(200) which burns up directly granular particles by making them into plasma state with streamer corona, electron unit(300) which burns up minute particles by means of DC ^{high} voltage and AC ^{high} voltage, ^{ionization} ~~ionic polarization~~ unit(400) which eliminates the noxious materials by generating lots of negative ions,

20

25 a screen unit(600) which removes NOx by generating

* illustrating working principle of a bottle-necked nozzle (105) in a partition unit (100) used to eliminate granular particles by means of slowing down the flow of exhaust gas, the

ozone with ultraviolet rays ^{and ions} in order to oxidize NOx into NO₂, which can be easily solved in water which is produced by Sellen's effect of PN diode (620) in screen unit (400), a union unit (700) which reduces engine
5 noises and shields electromagnetic waves irradiated from the above-mentioned unions (100, 200, 300, 400, 600), and ^{high-frequency} high voltage generator (not drawn) to supply high voltage to each unit.

10 Each unit will be explained in detail in the followings.

A partition unit (100) is shown in detail in Fig. 2 ^{(a) and (b)} and Fig. 3 ^{(a) and (b)}.

15 Referring to Fig. 2 (a) * a partition unit (100) comprises ionpin (110) which induces ^{high-frequency} ~~negative~~ high voltage to ionize air and granular particles in exhaust gas, an attractor electrode (120) in ^{the} ~~a~~ bottle-necked nozzle ⁽¹⁰⁵⁾ which induces ^{high-frequency high} ~~negative~~ voltage to accelerate exhaust
20 gas, a meshed collector electrode (130) which partitions granular particles, that is, larger particles drop down into the manhole below the meshed collector electrode (130) and small particles are passed through the collector electrode (130), and discharge poles (140).
25 ~~140~~ which burns up the dropped materials in manhole. ^(see page 10a)

Thus the partition unit (100) intaking exhaust gas from an engine preliminary separates exhaust gas into smoke and granular particles and then filters granular particles according to Fig. 2(a).

Fig.2(b) shows a brush corona which is discharged from ionpin(110) to charge the granular particles in exhaust gas.

(a) illustrates perspective view of partition unit guide assembly (190). These assemblies (190), as shown in Fig. 1, are arranged in
 5 Fig.3[^] shows ~~one of the embodiments where above~~ a row and stacked up and down in a casing of the partition unit (100). The ~~elements (110, 120, 130, 140) are mounted in a partition~~
~~unit (100), wherein a partition unit (100) comprises a~~ partition unit plate (180), ~~a ionpin (110) which~~ ^{occurs brush corona,} ~~ionizes~~
~~granular particles,~~ an air inlet hole (150) which takes
 10 exhaust gas into channel, a partition unit guider (160) where bottle-necked nozzle is mounted, and a partition unit pole (170) which burns up larger particles which is mounted at discharge poles (140, ~~140~~) below a collector electrode (130) in front of a ionpin (110) ^{and partition unit plate (180)}
^{on which above components}
 15 > (see page 11a) ^{are mounted.}

Fig.4(a) shows a unit cell (250) of the plasma unit (200) which is composed of several unit cells, wherein a plasma unit cell (250) comprises several plasma unit pole (210) in hemispheric shape which generate streamer
 20 corona to burn up the particles passed through the collector electrode (130) of the partition unit (100), several pole hole (220) in which the above plasma unit pole (210) are inserted, meshes ~~211~~ not shown in Fig.4(a) which act as a discharge electrode of the
 25 plasma unit pole (210) and a ground hole (260) which is

2. 7
- > Fig. 3(b) is a perspective view of the bottle-necked nozzle (105) mounted on partition unit guide assembly (190). Dissimilarly to Fig. 1 in which only the partition unit guide assembly (190) is assembled into the partition unit (100), there can be attached the bottle-necked nozzle (105) at the partition unit guide assembly (190) as seen from Fig. 3(b). As shown in Fig. 2(a), the partition unit pole (170) may be substituted for ion pin (110).

connected to the meshes(211).

Fig.4(b) shows the streamer corona which is generated between the plasma unit pole(210) in the plasma unit used as opposite electrode (see pp.12a-12d)
 5 cell(250) and meshes(211).

~~Fig.5(a) shows one set of a electron unit(300) which is composed of several units. One set of the electron unit(300) has a ionpin plate(320), a hole plate(310) and pole plate(350) wherein the ionpin plate(320) applied negative high voltage comprises many ionpin(110) which ionize the minute particles and generate electron wind, and many air inlet hole(150) which gas pass through, a hole-plate(310) with many air inlet hole(150) mounted on meshes(211) which act as discharge electrode for streamer corona, and a pole-plate(350) with many air inlet hole(150) and many plasma unit poles(210) which generate streamer corona~~

20 ~~to burn up the particles or an opposite electrode are possible to be installed in any direction such as in a vertical, horizontal or reverse direction against the flow of exhaust gas and the design of these plates can be varied to secure the durability and reliability. Also, both electrodes~~
 Fig.5(b) shows the embodiment that the above plates(310, 320, 350) are disposed in a electron unit(300). can be shaped in a various form such as circular, vertical or elliptic type of shape.

Practically, the efficiency of cleaning exhaust gas
 25 depends on size, shape, disposition of the plates(310,

For
example, if the unit pole(210) and the opposite
electrode(211) are supplied with high voltage such as
+10KV and -10KV respectively, streamer discharge
20 phenomenon is occurred between each pole, namely, unit
pole(210) and opposite electrode(211) as shown in
Fig.4(b). The electric figure of electron moving status
in such a streamer discharge phenomenon is shown in the
right side of Fig.4(b).
25 Plasma is a highly ionized gas in which particles

carrying a positive or negative electric charge exist equivalently in a differentiated state and which is of high density and entirely maintains electric neutrality. Especially streamer corona as illustrated in Fig.4(a) is
5 an electric discharge phenomenon in which luminous portions are seemingly mingled with each other between both electrodes. In other words, it is an electric discharge phenomenon in which luminous portions are widened in appearance since fine light flux are gathered
10 together.

In order to utilize such a corona discharge, as shown in Fig.4(b), the plasma unit pole(210) is installed in line with the flow passage of the plasma unit cell(250) and the meshes(211) which may be served as an opposite
15 electrode is installed on the flow passage. On the contrary, plasma unit pole(210) inserted, as shown in Fig.4(c), into the pole hole(220) of the connecting cap(255) mounted vertically to the flow passage of plasma unit cell(250) and opposite electrode(not shown) mounted
20 on the inner periphery opposite to the pole(210) can be used for above corona discharge.

Also, unless the exhaust gas reduction efficiency is required to be maintained high level, meshes(211) used as an opposite electrode can be removed. This means that
25 although the plasma unit pole(210) is installed in any

direction for example, in a vertical, horizontal or reverse direction to the flow passage of exhaust gas, much the same exhaust gas reduction efficiency and capacity can be acquired. Both of the electrode(210, 211) of the plasma unit cell(250) should be supplied with high-frequency high voltage in order to generate a streamer corona and thus the pointed end of the plasma unit pole(210) is dense with electrons thereby to generate corona plasma such as arc discharge caused by movements of electrons initiated with their inertia force by self-vibration.

As shown in Fig.5(a), the electron unit(300) for burning up minute particles with DC and AC high voltage comprises hole-plate(310), ion pin plate(320) and pole-plate(350) as one of unit set having same size.

The hole-plate(310) is a plate having a plurality of air inlet holes(330) arranged at regular intervals in every direction and each hole(330) makes the flow of exhaust gas smooth and meshes(211), not shown in Fig.5(a), mounted at the inlet hole(330) makes the flow of electrically charged particles smooth and at the same time acts as an electric discharge electrode.

The ion pin plate(320) applied with high-frequency high voltage is also a flat plate with which a plurality of

ion pins(110) are provided at the positions coaxial to the center of the air inlet holes(330) in the same number thereof.

By the way, each ion pin(110) generate a number of
5 electrons thereby to occur an electron wind, which causes a large number of ions to make it easy to capture the particles in the exhaust gas. Thus the ion pin plate(320) should be provided with a plurality of air inlet holes(331) located at the geometrical center of any
10 rectangle formed with 4 ion pins(110) adjacent to each other in every direction in order to make the flow of exhaust gas smooth similarly to above.

The pole-plate(350) equally sized to the hole-plate(310) and ion pin plate(320) has a plurality of plasma unit
15 pole(210) attached to the same location where the ion pin(110) of the ion pin plate(320) is located.

These plasma unit poles(210) are caused to discharge a streamer corona for burning up electrically charged particles captured by themselves. The pole-plate is also
20 provided with a plurality of air inlet holes(332) at the center of any rectangularly positioned 4 unit poles(210) similarly to the plate(320) for the purpose of maintaining a good flowing condition of electrically charged particles.

320, 350) and applied voltage and current. .

The appropriate area of cleaning exhaust gas in a electron unit(300) is characterized by :

$$5 \quad S = WNH$$

wherein distance between plates(310, 320, 350) is W, the height of plates(310, 320, 350) is H, the amount of exhaust gas is L, and the cross-sectional area for cleaning exhaust gas is S, if space is composed of n
10 plates.

The space between plates(310, 320, 350) is lane, and the ~~an~~ area of one lane is 2LH so that the total area of cleaning exhaust gas in a electron unit(300) is as the followings.

$$15 \quad A = 2NLH$$

DC-7KV is applied to each ion^{pin}~~pin~~ plate(320) and hole-plate(310) to ionize the minute particles by a ion^{pin}~~pin~~ pin(110) on the ion^{pin}~~pin~~ plate(320) and then to deposit
20 the ionized particles on the meshes(211) of the a hole-plate(310) and to cause electron wind between a ion^{pin}~~pin~~ plate(320) and a hole-plate(310).

~~High voltage pulse of~~
~~Ac~~ 10KV is applied to pole plate(350) to generate streamer corona to burn up the particles collected on
25 meshes(211).

Fig.5(c) is a circuit which supplies DC voltage to an ionpin^{pin}(110) mounted on an ionpin unit plate(320), comprises a transformer(T) to multiply voltage, a rectifying diode(D1, D2), a filtering resistor(R1, R2) to attenuate ripple signal, resistor (R3) the time constant of this circuit and capacitor(C1) which determine the time constant of this circuit.

FIG.5(d) is another circuit which supplies DC voltage to an ionpin^{pin}(110) mounted on a ionpin^{pin} unit plate(320). A circuit comprises a transformer(T) to multiply voltage, a rectifying diode(D3), resistor(R6) and capacitor(C2) which determine the time constant of this circuit when positive voltage is applied, and resistor(R6) and capacitor(C2) which determine the time constant of this circuit when negative voltage is applied.

Here, Electric field(E) generated at a ionpin(110)

$$E = \frac{V}{R(RC/RD)}$$

V : voltage applied at a ionpin(110)]

R : the radius of corona discharge generated at a

ionpin^{pin}(110)

RD : the radius of discharging current generated at

an ion^{pin}pin(110)

RC : the radius of meshes(211) set up on an air inlet hole(150).

- 5 Referring to Fig.6, the ionization unit(400) comprises many ionization cells(405) composed of an inner pipe(410) and disposed coaxially to the inner pipe (410) an outer pipe(420) [^] where gas passes a hole plate (430) served as through at high speed, and an opposite electrode(430) applied with high voltage. ^(see pp 15a, 15b and 15c) ~~And the point end(406) of~~
 10 ~~each ionization cell(405) is disposed between opposite electrodes(430).~~

~~Referring to Fig.7, the ionization unit(400) comprises a cell plate(409) on which several ionization cell(405) mounted, and hole plate(310, shown in Fig.1) which acts as an opposite electrode(430).~~

~~Fig.8 shows one set of screen unit(600) which is composed of several sets. One set of screen unit has~~
 20 plate A(630), plate B(640), and plate C(650), wherein it comprises plate A(630) and plate C(640) having several hexagonal holes(610) which generate UV rays to render O₂ into ozone and then NO_x into NO₃, and plate B(640) having several PN diodes(620) to generate H₂O by
 25 ~~dropping down the temperature of exhaust gas resulted~~

Both of the inner and outer pipes(410,
20 420) are formed into a tapered off cylinder like a
syringe.

The hole-plate(430) which acts as a opposite electrode
can be shaped into a flat plate as shown in Fig.1 and

provided with a plurality of air inlet holes(431) which
equal in number to the ion pin plate(320) of the electron
unit(300). A plurality of ionization cells(405) are
attached to the cell plate(409) assuming the form of flat
5 plate as seen from Fig.7 in the case of applying in
practice to the exhaust gas cleaning apparatus as shown
in Fig.1 and each ionization cell(405) is attached to the
location centered on the axis passing through the center
of any rectangle formed with 4 adjacent air inlet
10 hole(431).

Fig. 8 shows are set of screen unit(600) which is
composed of several sets. Each set of screen unit has the
first plate(601) made of ceramic material coated with
15 metal film which is 20-30 μ m thick and formed with
hexagonal hole(610) shaped as honeycomb, depicted in
detail by A, to generate UV rays and the second
plate(603) having PN diode(620) inserted into the
hexagonal holes(610) formed in the same way of the first
20 plate(601) in order to remove NOx gas with moisture
generated by temperature drop of the exhaust gas. The
screen unit(600) comprises the first and the second
plate(601, 603) stacked one by one as a module.

At this time, the operating voltage of the PN diode(620)
25 is 0.7V. Accordingly, the number of diode which is

needed, N, is specified as

$$N = \frac{\text{DC Voltage (V)}}{0.7 V}$$

~~from Sellen's effect.~~

Fig.9(a) shows a high-frequency voltage generator, wherein it comprises a firstly order coil applied with AC voltage, a transistor(T) to amplify signal, bias resistor(R7) to stabilize operation, a thirdly order coil applied with high voltage according to the turns ratio, a secondly order coil to modulate carrier having 50KHz-100KHz, a voltage multiplier circuit(D5), and capacitor(C5) to charge a thirdly order voltage.

Fig. 9(b) shows a voltage multiplier circuit(D5) in detail shown in Fig.9(a), which comprises a thirdly order coil to induce high voltage according to turns ratio, diode(D10,...,D80) to rectify AC voltage, high voltage is charged across capacitor(C5,...,C70). And the equivalent circuit of a voltage multiplier circuit(D5) is shown.

~~Fig.10 shows the entire external form the present invention, which is housed with metal in order to cut off the outer impact and to prevent irradiating engine noise and electromagnetic waves caused by each unit. The outlet of the case is forwarded to the ground.~~

20 Fig.10 shows the horizontal section of the union unit(700). This unit(700) comprises a mechanical-electric filter, to absorb engine noises and to shield electromagnetic waves to be radiated from corona

discharge process.

Namely, this unit is used to meet the regulations of EMI, EMC specification of this inventive apparatus. BY inserting a plurality of ferrite cores(720) into metal
5 house(710) and by winding wire(730) around ferits cores(720), this unit(700) shields EMI and EMC.

To shield EMI, EMC effectively, a wide range L and C with resonant frequency is recommended. A fine ceramic material can be substituted for the metal house(710) and
10 ferite material can be used for the cores(720) mounted outwardly to the metal house(710).

The ferite cores(720) are divided into 2 groups one of which is oprated for a positive magnetic field and another of which is operated for a negative magnetic
15 field so as to shut off the electromagnetic waves found near the exhaust port. Also, as shown in Fig.11, the entire external housing is prefered to have an exhaust port bended towrad the ground and is more effective when used duplicately in parallel arrangement.

20

Fig.11 shows the entire external form of the present invention, which is housed with metal in order to cut off the outer impact and to prevent irradiating engine noise and electromagnetic waves caused by each unit.

25 The outlet of the case is forwarded to the ground.

~~Finally, a union unit(700) in Fig.1 absorbs noise and shields electromagnetic waves, wherein it comprises a secondly order ferrite core to meet the regulations for noise absorber, EMI and EMC.~~

5

The operation of the apparatus in the present invention will be explained in the followings.

10 Partition unit(100) takes exhaust gas pushed out from an engine and sends it to a plasma unit (200) fluently. In a partition unit(100), EHD(electro-hydro dynamics) method is applied between inhaling site(a-a) and exhaling site(b-b) to accelerate the flow of exhaust
15 gas and electrostatic method of Coulomb's force is used.

Exhaust gas mixed with air is inhaled into a partition unit(100), and the granular particles in exhaust gas are decomposed and ionized into negatively. The
20 negatively charged particles pass through a bottle-necked nozzle, where the speed of the gas accelerates by means of EHD method.

In addition, negatively charged particles accelerates much more by voltage difference between ~~an ionpin~~ ^{the ion pin} (110)
25 ^{then} and ~~an~~ attractor electrode(120) induced negatively, and

phenomenon prevents
this ~~phenomena~~ prevent exhaust gas from staying or
slowing down in the partition unit(100). We call the
above process as EHD(electro-hydro dynamics) method.
Exhaust gas after passing through ^{the} ~~a~~ nozzle is diffused
5 to a collector electrode(130), where the diffusion
theory of waveguide is applied. That is, exhaust gas
diffused after passing through ^a ~~the~~ narrow space can
spread widely without slowing down the speed. The
negatively charged particles are attracted by
10 electrostatic force on the collector electrode(130)
which is made of metal mesh and larger particles which
can not pass through the collector electrode(130) of
metal mesh(211) drop down into the manhole where one
set of discharge poles(140, ~~149~~) are disposed to burn
15 up large particles.

While large particles in exhaust gas are eliminated by
burning up in a manhole where small particles may pass
through the collector electrode(130). It is preferred
that ^{the} ~~a~~ partition unit pole(170) has a round head in
20 shape to increase ignition energy.

The high speed of exhaust gas is helpful in preventing
the collector electrode(130) filled up with small
particles.

25 In ^{the} ~~a~~ plasma unit(200), particles are burned by applying

~~that is to say, particles which have been passing through the collector electrode (130) are burned up again while passing through the plasma cell (250),~~

plasma process, where plasma means that particles are divided into positive and negative particles, of which the amounts are the same, and therefore they show neutral state in total.

- 5 Small particles which can pass through the collector electrode (130) ^{are burned} ~~burn~~ up in a plasma unit cell (250) by streamer corona generated between a plasma unit pole (210) applied with + voltage and mesh (211) applied with - voltage.

- 10 ~~At this time, since the plasma generated at the plasma unit (200) have~~
~~In the present invention, the streamer corona is~~
~~a tendency to maintain electric neutrality because of their equal density~~
~~generated by using a hemispheric plasma unit pole (210).~~
~~of positive and negative electric charge, when~~
~~By using a hemispheric plasma unit pole, a large amount~~
~~of streamer corona can be generated.~~

- 15 ~~When the high voltage is applied, for a short time,~~
~~flowed into the plasma unit cell (250) are charged and burned up by~~
~~particles in exhaust gas are charged and burned up by~~
 flame discharge which occurs between a plasma unit pole (210) and mesh (211).

- In addition, particles oscillate due to property of
 20 attracting each other by electrostatic force and this prevents the meshed net (211) filled up with particles.
 Further, electrons oscillate in plasma state, and electron's oscillation frequency enhance the particles oscillation.

- 25 Oscillation frequency (f_k) is characterized by;

$$f_k = 8.9 \times 10^3 \sqrt{N}$$

, where N is electron density and oscillation frequency depends on air pressure.

> (see pg. 20a)

5 ~~In order to clean exhaust gas more efficiently, exhaust~~
gas is conveyed to electron unit(300) after passing
through plasma unit(200).

The air inlet hole(150) of hole plate(310) in plate set
is composed of metal meshed net[211, not drawn in
10 Fig.5(a)] through which exhaust gas can flow freely,
and metal meshed net(211) acts as discharge electrode.
AC high voltage is impressed to pole plate(350) and
hole plate(310) in order to generate streamer/corona to
burn up minute particles. And oscillating AC voltage
15 prevents the metal meshed net[211, not drawn in
Fig.5(a)] filled up with particles.

DC high voltage is impressed across hole-plate(310) and
ionpin plate(320) to generate electric wind by
ionpins(110) on the ionpin plate(320) which pushes
20 particles to hole plate(350) in order to enhance the
efficiency of corona discharge between hole plate(310)
and pole plate(350).

The above-mentioned process will be explained
25 systematically in the following.

Then, the exhaust gas passes through the electron
25 \ unit(300) is provided with air inlet holes(330) for the
exhaust gas to pass through uniformly. At this time,
meshes such as the meshes(211) can be mounted to the flow
passage as a discharge electrode. AC high voltage is
impressed between the pole-plate(350) and the hole-
5 plate(310) in order to generate electric wind from ion
pin(110) of the ion pin unit plate(320) and thereby to
push the particles toward the hole-plate(310). Thus the
minute particles passing through the meshes are burned up
again effectively by the corona discharge generated
10 between the hole-plate(310) and the pole-plate(350)

The noxious materials in exhaust gas are nearly cleared by several steps, wherein large particles are ~~preliminary burned up to be~~ ^{first} removed in partition unit(100), and then small particles passed through the partition unit(100) are removed in plasma unit(200) by streamer corona, and then minute particles are eliminated in electron unit(300).

There are noxious chemical materials in exhaust gas, and two different methods are used to remove noxious chemical materials in the present invention.

First, noxious materials are removed with negative ions generated by ionization unit(400). Ionization unit(400) which generates ultraviolet rays between outer pipe(420) and opposite electrode(430), and this ultra-violet rays generate lots of negative ions.

While the general negative-ion generator has a pointed-end in order to produce negative ions, negative ion generator of the present invention has an ionization cell(405) structure which has inner cylindrical wall dividing the space into two routes, that is, inner pipe(410) and outer pipe(420) in addition to the known form. By the above-mentioned ionization cell(405) structure, the negative ion generator of the present invention emits more negative ions several thousand

times than the usual negative ion generator, while the noxious gases passing through at very high speed.

We call this method as plasma jet, where the appropriate distance between outer pipe(420) and
5 opposite electrode(430) should be maintained in order to generate negative ions in a large amount.

Corona is also generated at the pointed end of plasma jet, and its temperature is 800°C-1500°C.

The noxious material molecules are excited by ultra-
10 violet rays and the excited noxious materials combine negative ions and ozones to be changed into other materials. And in this process noxious positive ions are also removed.

15 In order to remove NOx which is not removed in the above-mentioned ionization unit(400), screen unit(600) is used in the present invention.

~~The screen unit(600) comprises ceramic plate A(630), (603) ceramic plate C(650) and ceramic plate B(640) having~~
20 hexagonal holes(610) in which PN diodes(620) are disposed.

When 10K voltage is impressed to plates, ultra-violet rays are generated around hexagonal hole(610) in a large amount, and ultra-violet rays let O₂ be changed
25 into ozone.

Ozone is generated in a large amount when thickness of metal is 20 μ m-30 μ m

The impedance matching is important, since the printed metal may be separated from ceramic plate, if higher
5 voltage than 1KV is impressed for a long time.

Also the separation of the printed metal from ceramic plate can be prevented by scratching the ceramic plate.

Such an apparatus has been used for sterilization of
10 food or for generator of ozone, but it has been never used for eliminating of smoke.

In addition, PN diodes(620) mounted in hexagonal holes(610) of plate B(640) cause temperature dropping
15 by Sellen's effect to condense H₂O into water.

Ultra-violet rays are generated in a large amount when coated surfaces of the first plate (601) and
high voltage is impressed to the plate A(630) and plate, the second
plate (603) faced to each other,
C(650), and this ultra-violet rays make oxygen into
ozone which renders NO_x into NO, which can be easily
20 solved in water.

During this process, the efficiency of removing NO_x and connecting the PN diodes (620)
will be enhanced by taking air into plates in serial and parallel
arrangement.
The method of dropping temperature by using PN
diodes(620) is called as Sellen's effect and this
25 method has been used for refrigerator, but has never

been used for eliminating smoke.

~~In the present invention, PN diodes (620) are connected~~
in serial and parallel to induce Sellen's effect.

5 The operating voltage is 0.7V.

Accordingly, the number of diode which is needed, N, is
specified as;

10
$$N = \frac{\text{DC voltage (V)}}{0.7V}$$

Most of noxious chemical gas in exhaust gases is
removed in ~~an~~ ^{the} ionization unit (400) and a NOx, which is
not filtered in ~~an~~ ^{the} ionization unit, is removed through
15 ~~a~~ ^{the} screen unit (600).

Therefore, the granular ingredients and noxious
chemical gas of exhaust gases are completely purified.

A high voltage generator with a high frequency
20 comprises by a high frequency oscillator and a high
voltage rectifier with transformer.

The high voltage generator with a high frequency of
this invention supplies positively and negatively
polarized high voltage.

25 A high voltage generator in the present invention is
different from the usual one in the point that it has

a special circuit which needs an isolation strength and a feedback circuit to shutdown a firstly order coil voltage, if a secondly order coil is abnormal.

5 This high voltage generator shown in FIG 9(a) comprises a transistor to amplify a modulated signal, a thirdly order coil to induce a high voltage, a secondly order coil to shutdown a firstly order coil voltage, when second orderly coil does not work well, a capacitor(C5)
10 to charge voltage, and a voltage multiplier circuit (D5) to multiply a voltage.

A voltage multiplier circuit(D5) is used to multiply voltage needed for the above-mentioned units(100, 200, 300, 400, 600), wherein E is a charged voltage across
15 a capacitor(C5), 2E is a charged voltage across a capacitor(C10), 3E is a charged voltage across a capacitor(C20), 4E is a charged voltage across a capacitor(C30), 5E is a charged voltage across a capacitor(C40), 6E is a charged voltage across a
20 capacitor(C50), 7E is a charged voltage across a capacitor(C60), 8E is a charged voltage across a capacitor(C70)

A ceramic resistor filter(R100) is used to prevent circuit breakdown, and to avoid dangerous situation
25 which are caused by the remained high voltage across

capacitor(C10,...,C70) in case of a thirdly order coil voltage "OFF".

As modulating a carrier(400KHz) and a signal(50KHz-100Hz) at a secondly order coil, a transistor outputs
5 specially high voltage without excessive current.

To reverse an output voltage polarity, the connection of diode(D10,...,D80) is reversed.

As E is a charged voltage across a capacitor(C5), discharge voltage(Vo)

$$10 \quad V_o = \frac{C_1 E}{C_1 + C_2} \left\{ 1 - e^{-\frac{C_1 + C_2}{C_1 + C_2 R_s}(t)} \right\}$$

15 This invention can contain a union unit(700), which comprises a mechanical-electric filter, to absorb engine noises and to shield electromagnetic waves to be radiated from corona discharge process.

20 Namely, this unit is used to meet the regulations of EMI, EMC specification of this inventive apparatus. By inserting ferrite cores into metal house and by winding wire around ferite cores, this unit(700) shields EMI and EMC.

25 To shield EMI, EMC effectively, a wide range L and C with resonant frequency is recommended.

As above-mentioned, this invention relates to a method

and an apparatus to clean exhaust gas of an internal
combustion engine, an external combustion engine and
anti-pollution equipments ^{and} ~~an~~ so on. As this invention
can clean exhaust gas and reduce noises, it can be
5 substituted for a noise absorber, for example, the
muffler of automobiles.

10

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what is claimed is:

1. A method for cleaning exhaust gas by using high voltage field, which comprises:

- 5 (a) step 1, diffusing exhaust gas at high speed by using the bottle-necked attractor electrode(120) and burning up the partitioned large particles with corona discharge;
- (b) step 2, burning minute particles which are not
10 removed through step 1 under plasma atmosphere;
- (c) step 3, burning gaseous particles by using AC voltage and DC voltage;
- (d) step 4, removing noxious gas by using lots of negative ions; and
- 15 (e) step 5, oxidizing NOx with ozone generated by ultraviolet ray and removing NOx by dissolving in H₂O generated from heat exchanging method by PN diodes.

20 2. A method for partitioning exhaust gas by using high voltage field, which comprises;

- (a) ionizing particles and air by using electric discharge;
- (b) diffusing the ionized particles and air to the
25 collector electrode(130) at high speed by using

the bottle-necked attractor electrode(120);

(c) partitioning particles, wherein small particles pass through collector electrode(130) and large particles drop down to deposited in the manhole;

5 and

(d) burning up large particles with electric discharge.

3. A method for burning up particles in exhaust gas by using high voltage field, characterized in that
10 particles in the plasma state are burned up by using oscillatory corona discharge;

4. A method for burning up particles as in Claim 3, characterized in that corona discharge is a streamer
15 corona having a large discharging area.

5. A method for burning up minute charged particles in exhaust gas by using high voltage field, which comprises;

20 (a) burning up charged minute particles by using corona discharge generated by AC voltage; and
(b) burning again minute particles which are not burned up in the step(a) by using DC voltage.

25 6. A method for burning up charged particles as in

Claim 5, characterized in that corona discharge is a streamer corona having a large discharging area.

7. A method for neutralizing noxious gas in exhaust gas by using plasma jet which comprises;
- (a) generating lots of negative ions; and
 - (b) decomposing noxious gas by using negative ions.

8. A method for neutralizing noxious gas as in Claim 7, wherein a sharp pointed-end plasma jet generating negative ions comprises a cylindrical inner pipe and a cylindrical outer pipe ^{tapered off and} divided by cylindrical wall.

9. A method for removing NOx in exhaust gas by using high voltage field, which comprises;
- (a) generating ultraviolet rays,
 - (b) oxidizing NOx with ultraviolet rays; and
 - (c) dissolving oxidized NOx in H₂O which is generate^d by using heat exchanging method of PN diodes.

10. A method for removing NOx as in Claim 9, wherein a step of generating ultraviolet rays by using a plurality of multi-holed plates comprises;
- (a) printing electrode circuit pattern with metal on

the plate;

(b) printing electrode circuit pattern on opposite electrode in the same way; and

(c) supplying high voltage to each electrode for generating ultraviolet rays

11. A method for removing NOx as in Claim 9 wherein each plate has lots of polygonal holes for generating ultraviolet ray effectively.

12. A method for removing NOx as in Claim 10 or Claim 11, wherein electrode circuit pattern on the plate is printed with metal of which thickness is 10 μ m - 50 μ m.

13. A method for removing NOx as in Claim 9, wherein heat exchanging method for condensing H₂O is induced by arranging PN diodes in serial or in parallel between plate and plate.

14. A method for removing NOx as in Claim 11, wherein ultraviolet rays are generated from hexagonal holes when supplying power to plates.

15. A method for generating high voltage for

cleaning exhaust gas, wherein a signal is modulated by a carrier

16. A method for generating high voltage as in
5 Claim 15, wherein a signal is modulated by a carrier of 400KHz-500KHz.

17. Apparatus for cleaning exhaust gas by using high voltage field, which comprises;

10 (a) partition unit(100), which takes exhaust gas into and then diffuses to the collector electrode(130) where particles are partitioned, and burns up large particles with corona discharge; /

(b) plasma unit(200), which burns minute particles
15 which pass through partition unit(100) by using ~~steam~~ corona;

(c) electron unit(300), which burns gaseous particles by using AC voltage and DC voltage

(d) ionization unit(400), which ~~removes noxious gas by~~ oxidizes NOx with ozone generated by

20 ~~using negative ions, and~~ ultraviolet ray and removes NOx by dissolving in H₂O generated by temperature dropping induced by PN diodes.

~~(e) screen unit(600), which oxidizes NOx with ozone~~ generated by ultraviolet ray and removes NOx by dissolving in H₂O generated by temperature dropping induced by PN diodes.

18. Apparatus for cleaning exhaust gas Claim 17, comprises further union unit(700) in addition to said units (100, 200, 300, 400, 600), wherein union unit(700) shields electromagnetic wave and reduces
5 noise.

19. Apparatus for partitioning exhaust gas by using high voltage field, which comprises;
(a) ionpin(110) ionizing particles with high voltage to
10 remove particles;
(b) partition unit guide(160) to make the smooth flow of exhaust gas;
(c) partition unit plate(180) mounted a plurality of air inlet holes(150) to make the smooth flow of
15 air;
(d) attractor electrode(120) to supply voltage to the bottle-necked nozzle where the flow of exhaust gas accelerates;
(e) collector electrode(130) filtering particles; and
20 (f) partition unit pole(170) mounted with discharge electrodes (140, 140) to burn up large particles dropped in the manhole.

20. Apparatus for partitioning exhaust gas as in
25 Claim 19, wherein nozzle part acts as electrode in

whole tube.

21. Apparatus for partitioning exhaust gas as in Claim 19, wherein said partition union pole(170) is in the shape of sphere to enhance ignition of particles.

22. Apparatus for burning up particles in exhaust gas composed of plasma unit(200) which contains a plurality of plasma unit cells(250), wherein a plasma unit cell comprises

- (a) plasma unit pole(210) to generate streamer corona;
- and
- (b) meshed net(211) to act as discharge electrode.

23. Apparatus for burning up particles as in Claim 22, wherein streamer corona occurs between said plasma unit pole(210) and said meshed net(211).

24. Apparatus for burning up particle as in Claim 22 or Claim 23, said plasma unit pole(210) is formed in hemisphere which one side is flat to cause streamer corona.

25. Apparatus for burning up particles as in Claim 22 or Claim 23, electron density between plasma poles

is $10^3 - 10^5/\text{cm}^3$.

26. Apparatus for burning up particle as in Claim 22, or Claim 23, the number of oscillation across
5 plasma poles is 10MHz.

27. Apparatus for burning up charged particles composed of electron unit(300) which contains a plurality of sets, wherein one set comprises
10 (a) ionpin plate(320) having air inlet hole(150) having mounted with ionpins(110) to generate electric wind;
(b) hole plate(310) having air inlet hole(150) mounted with meshed net(211) which acts as opposite
15 electrode; and
(c) pole plate(350) mounted with plasma unit poles(210) generating streamer corona

28. Apparatus for burning up charged particles as
20 in Claim 27, wherein said ion pin plate(320) is as matrix structure which comprises;
(a) ion pin(110) to generate electric wind; and
(b) air inlet hole(150) for smooth air flow.

25 29. Apparatus for burning up charged particles as

in Claim 27, said hole plate(310) is formed with a number of air inlet holes(150) in which have meshed net for smooth air flow.

5 30. Apparatus for neutralizing noxious gas in exhaust gas composed of ionization unit, which comprises ionization unit cells(405) generating negative ions and ultraviolet rays by plasma jet formed as cylindrical outer pipe(420) and cylindrical inner
10 pipe(410) with a sharp pointed-end.

31. Apparatus for neutralizing noxious gas as in Claim 30, said ionization unit(400) comprises;

(a) cell plate(409) mounted ionization cell(405) as
15 matrix form; and
(b) hole plate(310) having air inlet hole(150) in which meshed net is cross-sectionally mounted.

32. Apparatus for removing NOx, wherein plate
20 B(640) arranged with PN diodes(620) to drop temperature the first plate (601) and the second plate (603).
are mounted between plate A(630) and plate C(650).

33. Apparatus for removing NOx as in Claim 32,
 first plate (601) second plate (603)
wherein said plate A(630) and plate C(650) used as an
25 electrode have a lot of hexagonal holes(610).

34. Apparatus for removing NOx as in Claim 32, wherein said PN diodes(620) are connected in a serial or parallel to induce temperature dropping called as Sellen's effect

5

high-frequency

35. Apparatus for generating ^{high} high voltage to supply high voltage to said partition unit(100), plasma unit(200), electron unit(300), ionization unit(400) and screen unit(600)

- 10 (a) transistor(TR) to amplify signal;
(b) a firstly order coil supplied with high voltage;
(c) a thirdly order coil generating high voltage according to turn ratio;
(d) ceramic resistant filter(R100) to discharge the
15 remained voltage at a thirdly order coil when the switch is off.
(e) feedback circuit connecting a secondly order coil and the base of transistor.

- 20 36. Apparatus for generating high voltage as in Claim 35, wherein said high voltage generator comprises further voltage multiplier circuit(D5) to multiply a thirdly order voltage and capacitor(C5) to charge a thirdly order voltage

25

37. Apparatus for removing noise and electromagnetic wave composed of union unit(700), wherein the outer part is formed as ferrite core for shielding electromagnetic wave and electric field in the air.

38. Apparatus for removing noise and electromagnetic wave as in Claim 37, wherein said ferrite core is connected in 2 stages serially, the first stage is operated in positive magnetic field and the second stage is operated in negative magnetic field.

39. Apparatus for absorbing noise by using high voltage field, which comprises;

- (a) partition unit(100), which takes exhaust gas into and then diffuses to the collector electrode(130) where particles are partitioned, and burns up large particles with corona discharge;
- (b) plasma unit(200), which burns minute particles which pass through partition unit(100) by using steamer corona;
- (c) electron unit(300), which burns gaseous particles by using AC voltage and DC voltage
- (d) ionization unit(400), which removes noxious gas by

using ~~negative~~ ions; and

(e) screen unit(600), which oxidizes NOx with ozone
generated by ultraviolet ray and removes NOx by
dissolving in H₂O generated by temperature
5 dropping induced by PN diodes.

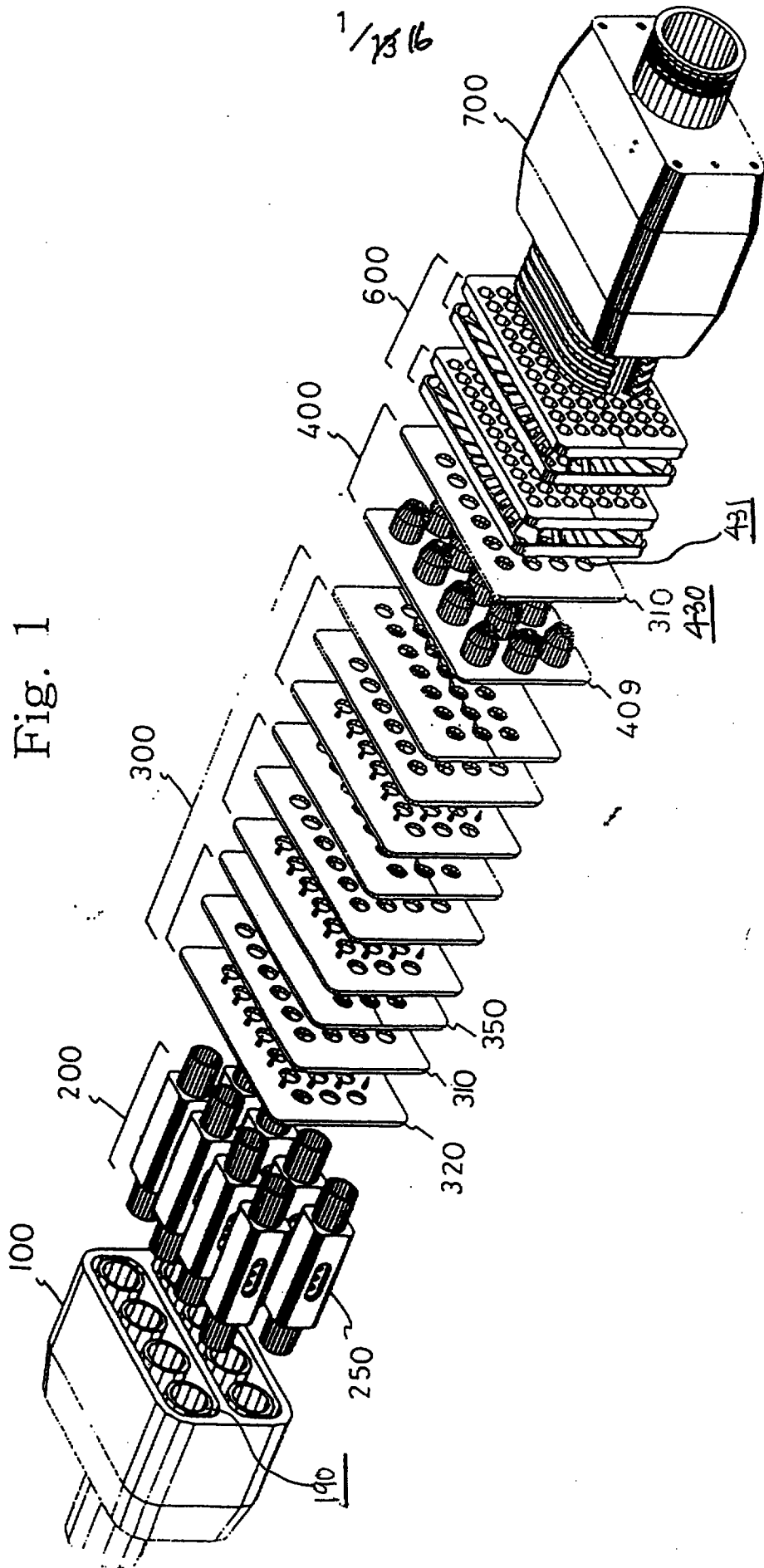
(f) union unit(700) which shields electromagnetic waves
and reduces noise.

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Fig. 2(a)

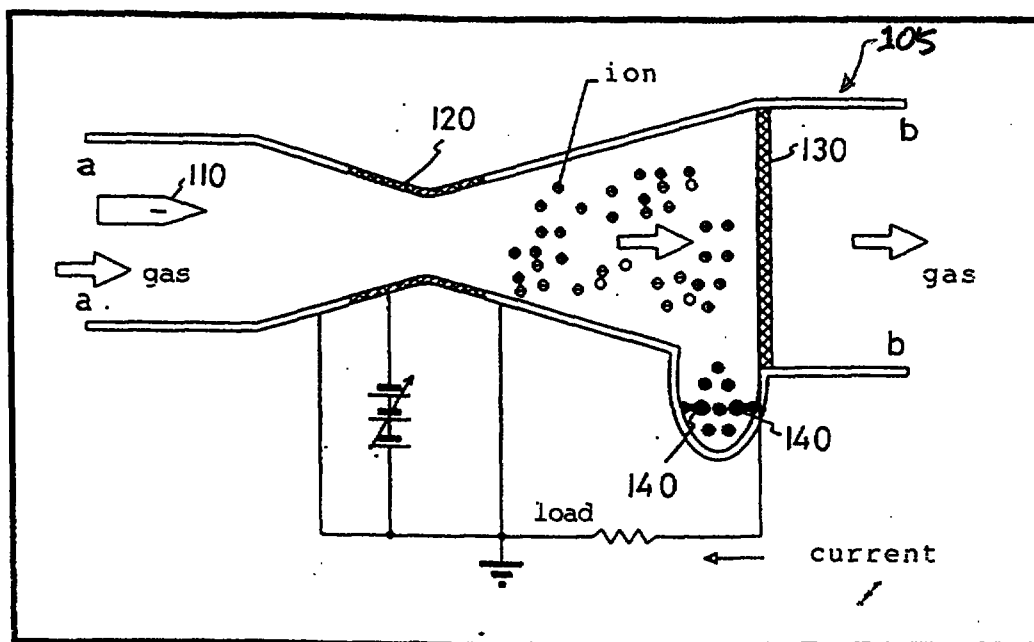


Fig. 2(b)

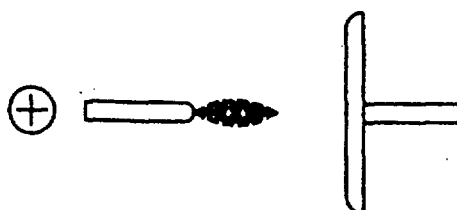


Fig. 3(a)

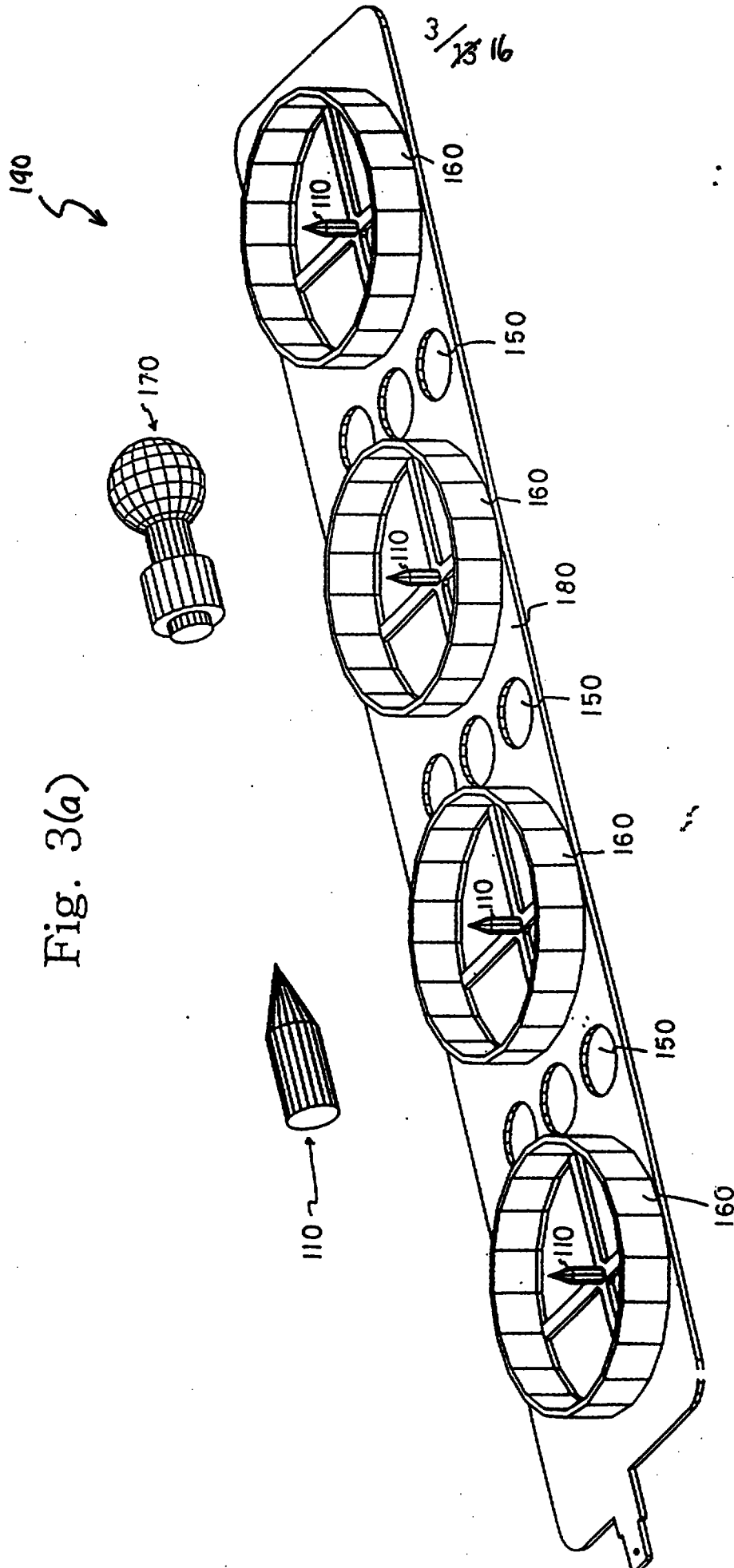
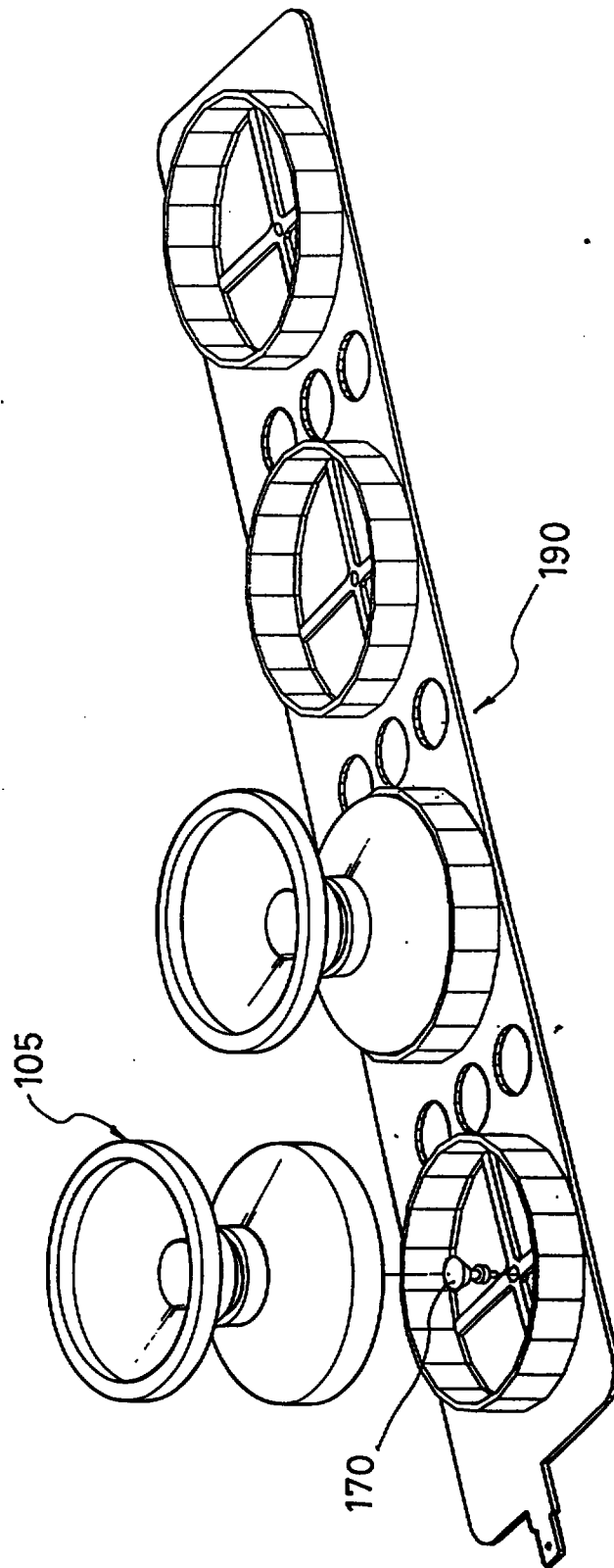
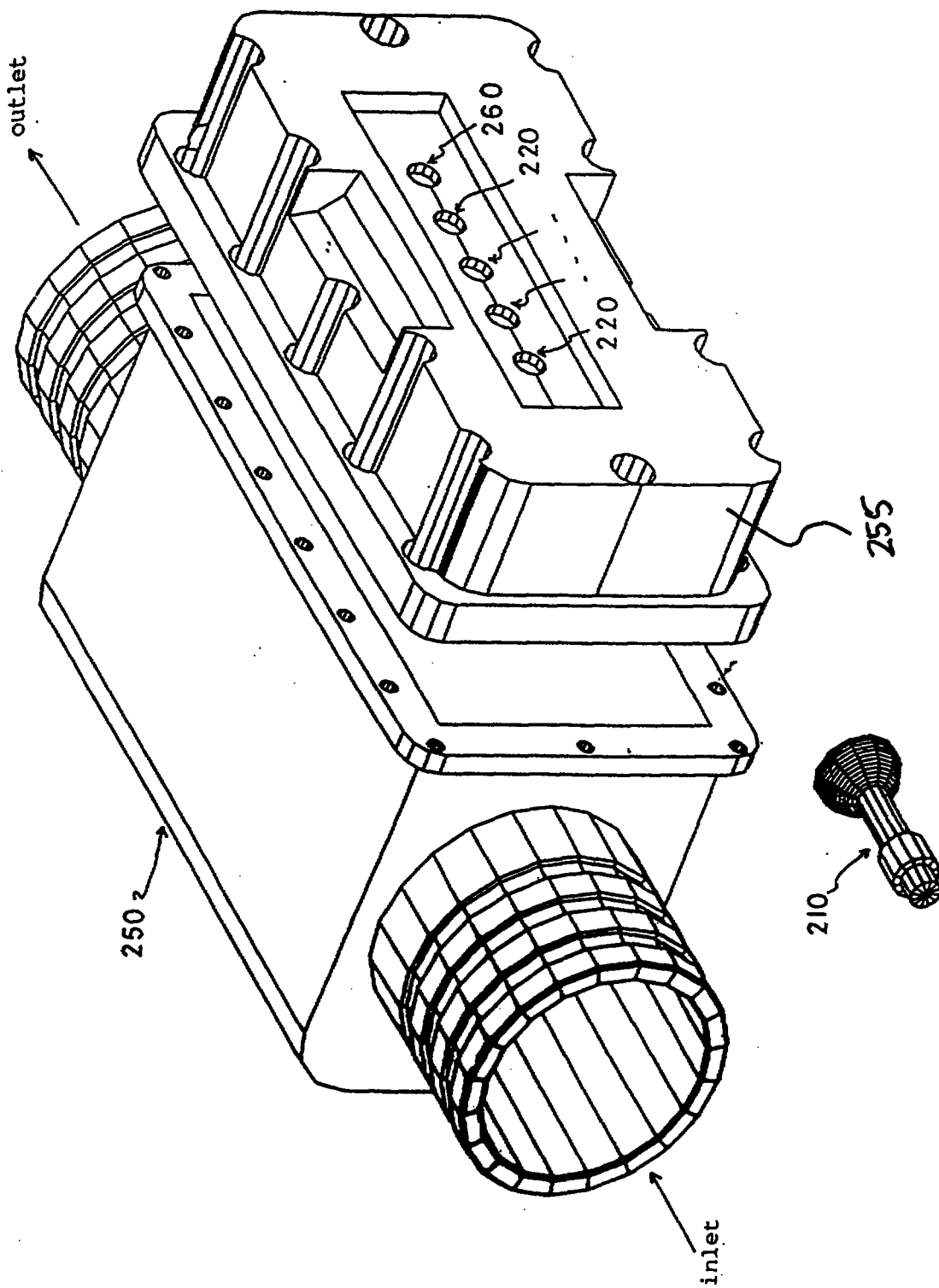


Fig. 3(b)



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Fig. 4(a)



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Fig. 4(b)

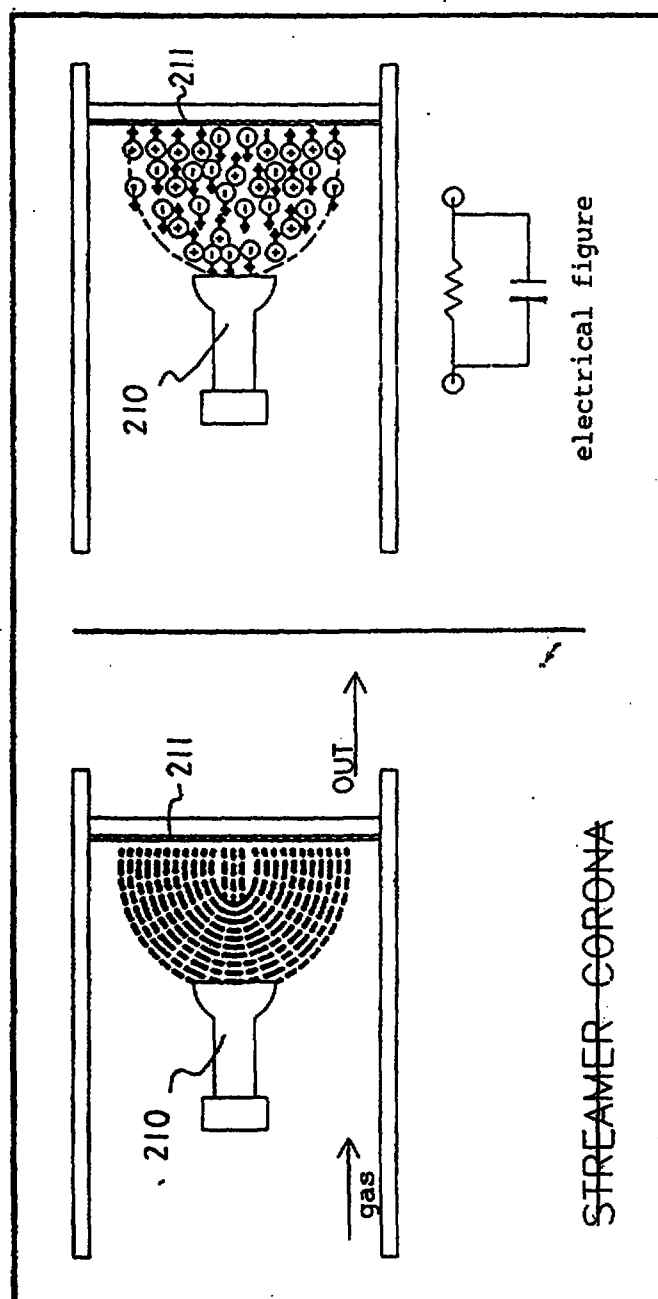
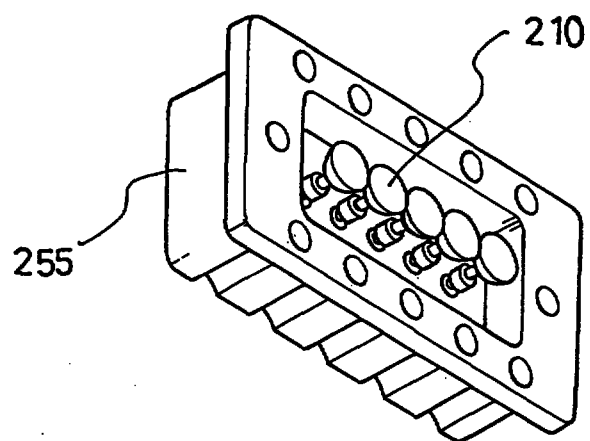
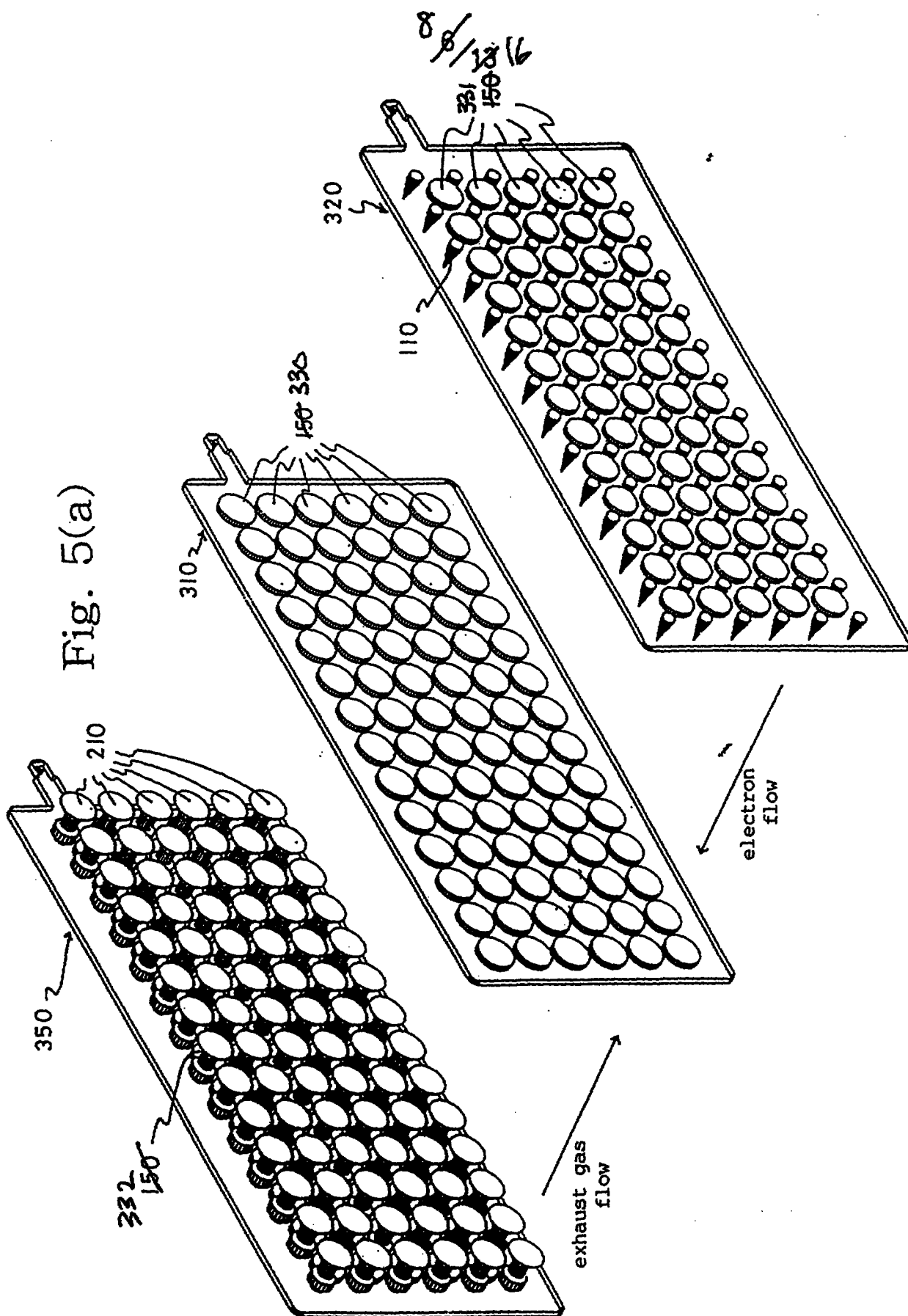


Fig. 4(c)





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Fig. 5(b)

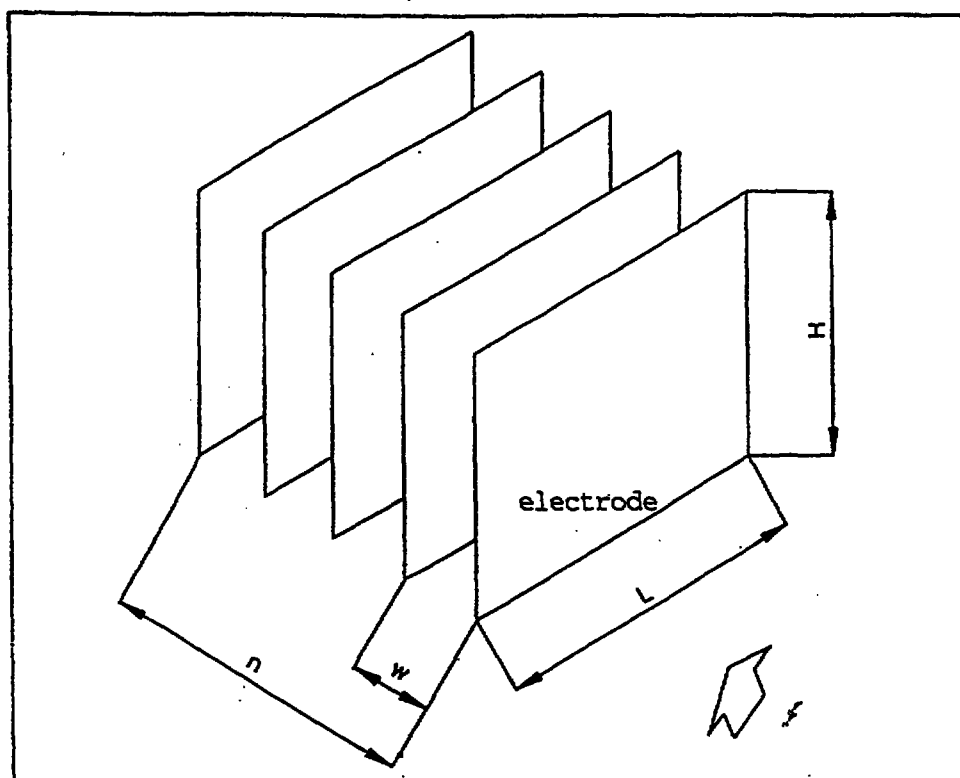
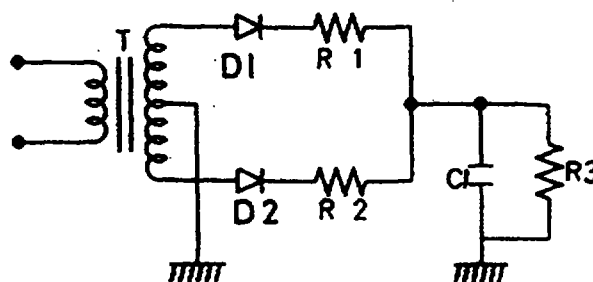


Fig. 5(c)



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Fig. 5(d)

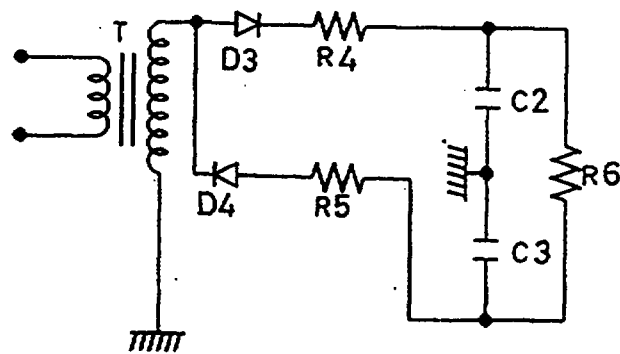
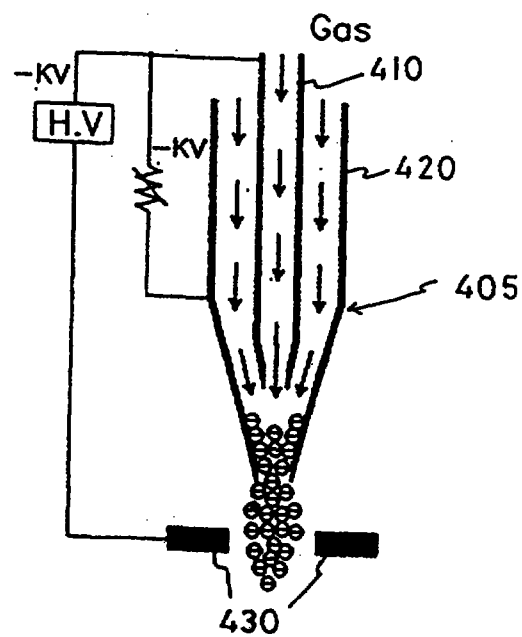


Fig. 6



11/8/13/16

Fig. 7

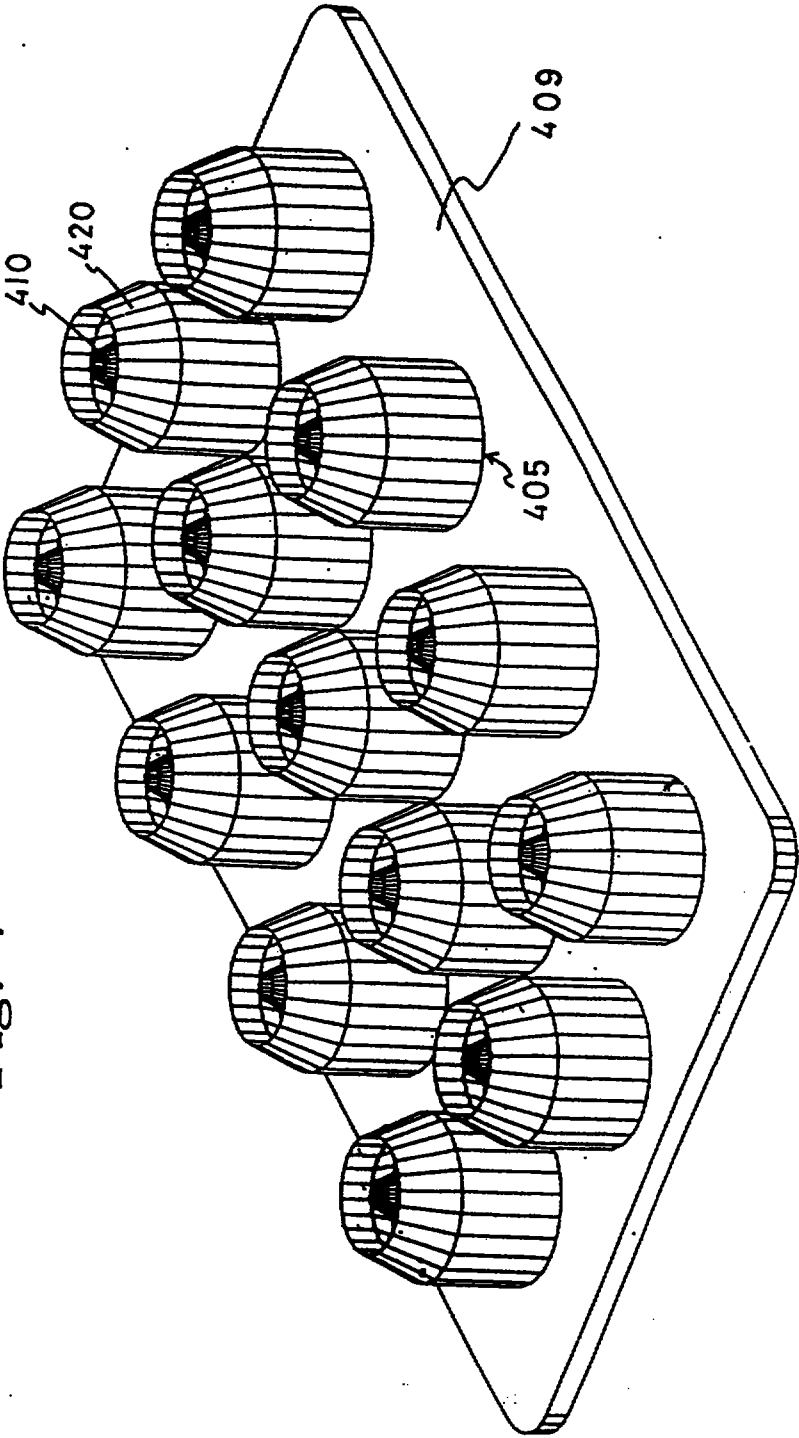
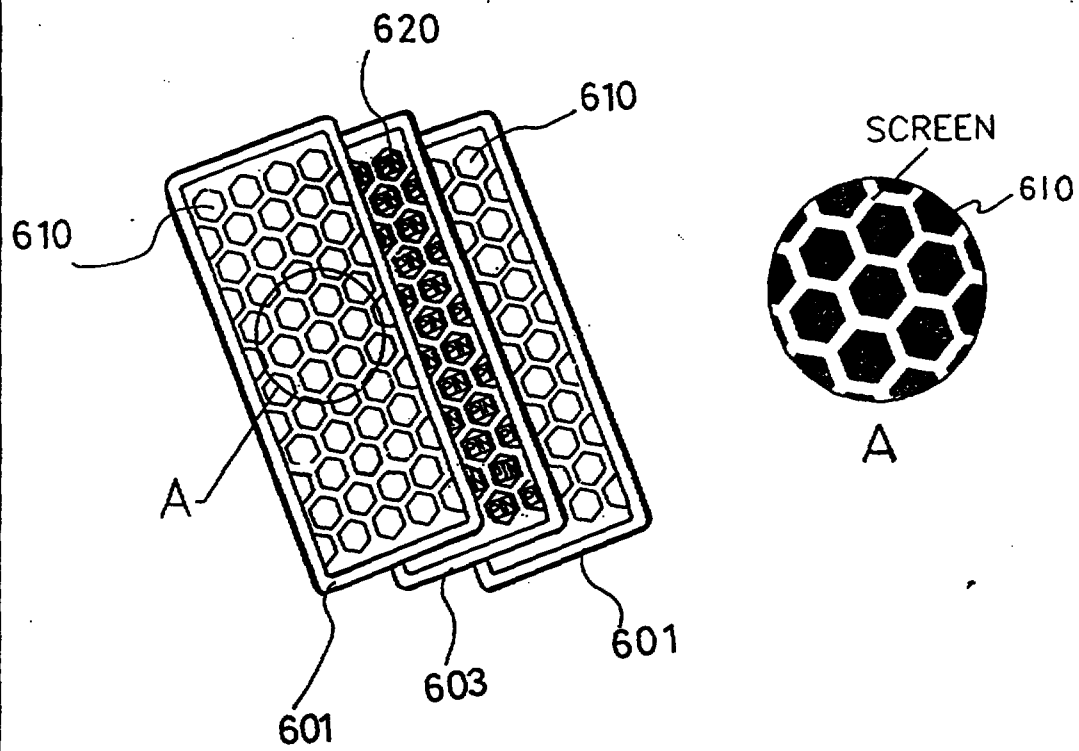
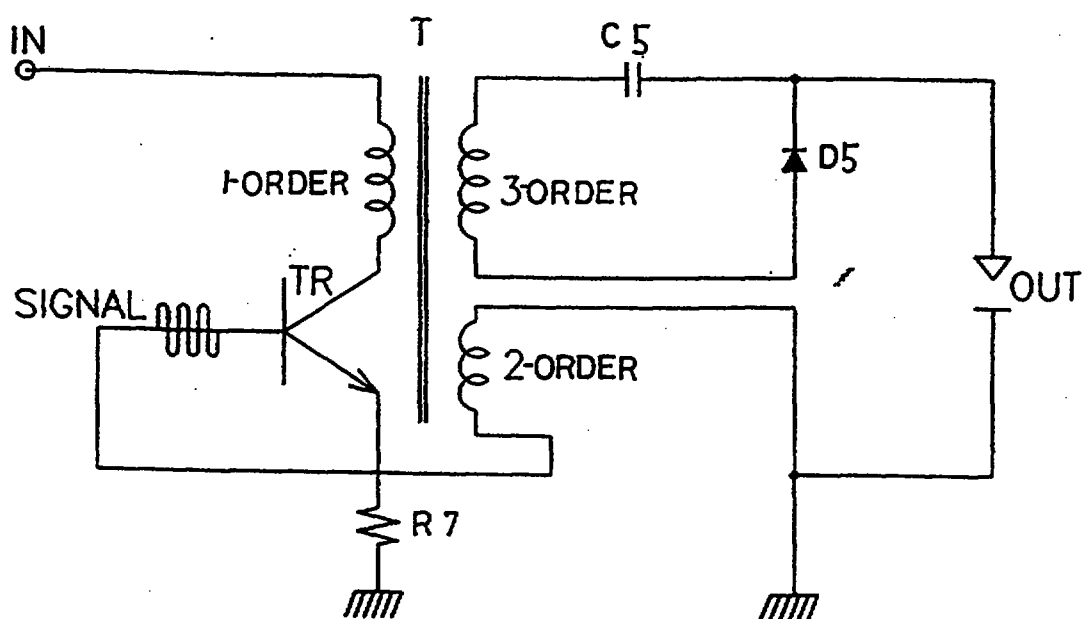


Fig. 8



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21/18/6

Fig. 9(a)



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Fig. 9(b)

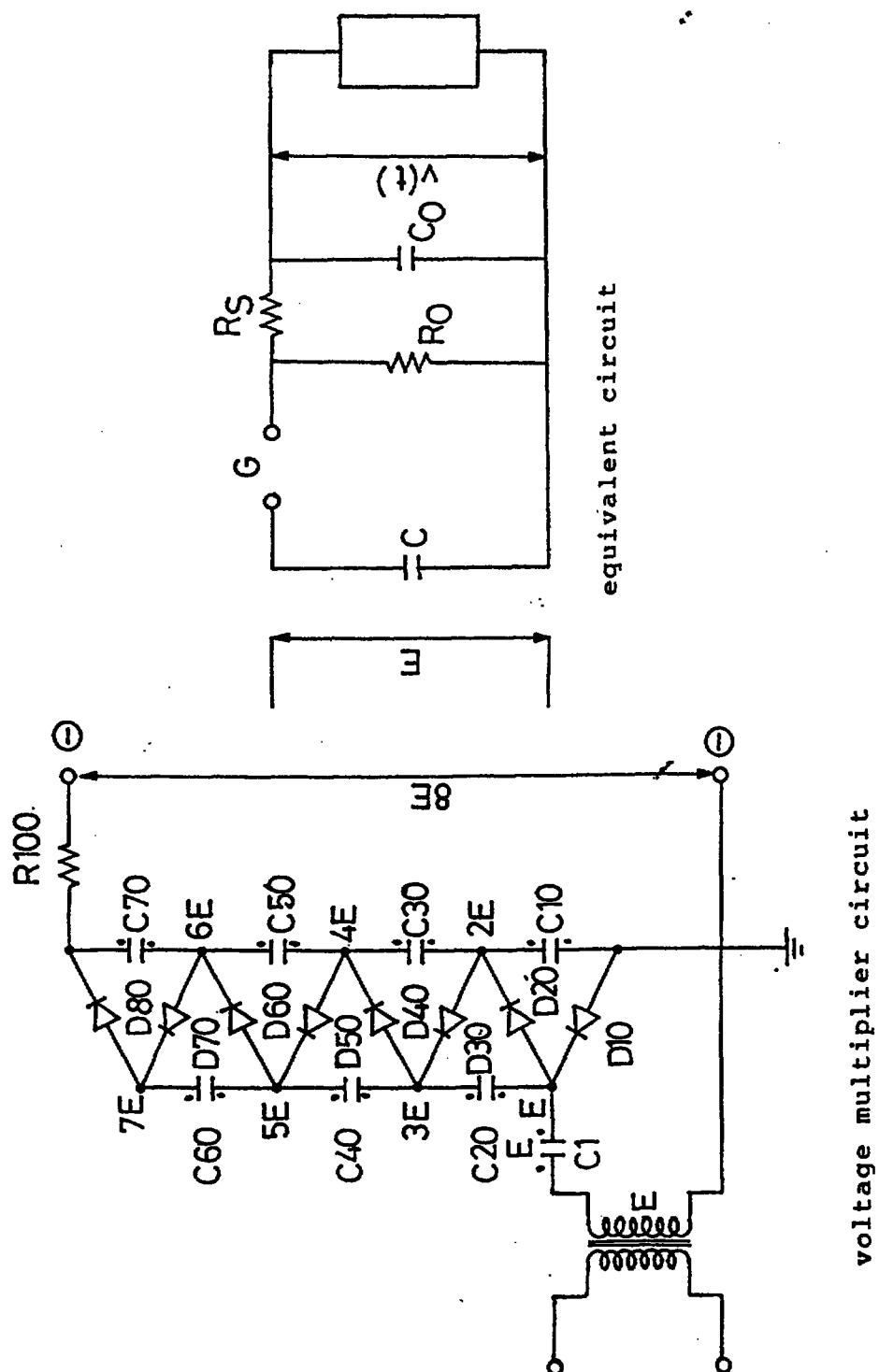
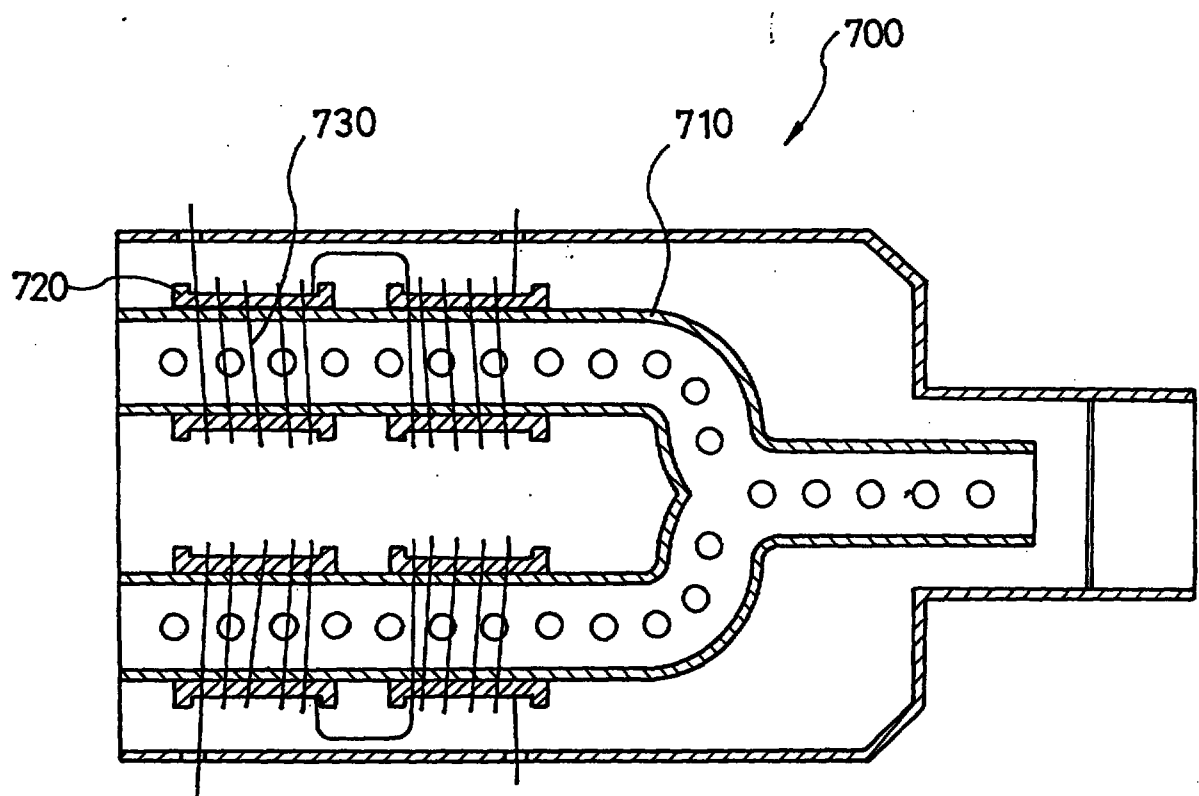


Fig. 10



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13/13/6

Fig. 10

