United States Patent [19]

Ikebe et al.

[11] **3,762,135**

[45] **Oct. 2, 1973**

[54] **SEPARATING DEVICE FOR FINE PARTICLES, SUCH AS CARBONS AND THE LIKE**

[75] Inventors: **Kenji Ikebe; Shigeru Tano,** both of Kawasaki-shi, Kanagawa-ken; **Kiyomi Sasaki,** Machida-shi, Tokyo; **Tatsuki Mayusumi,** Tokyo, all of Japan

[73] Assignee: **Tokyo Roki Kabushiki Kaisha,** Kanagawa-ken, Japan

[22] Filed: **Aug. 31, 1971**

[21] Appl. No.: **176,462**

[52] **U.S. Cl.** **55/100,** 55/124, 55/127, 55/128, 55/138, 55/154, 55/278, 55/330, 55/337, 55/457, 55/484, 55/510, 55/DIG. 30, 60/278, 60/311, 210/223

[51] **Int. Cl.** **B03c 1/02**

[58] **Field of Search** ..... 55/3, 100, 124, 127, 55/128, 138, 154, 278, 330, 337, 457, 484, 510, DIG. 30; 210/222, 223; 60/278, 279, 311

[56] **References Cited**

UNITED STATES PATENTS

2,974,981	3/1961	Vervest et al.	210/222 X
3,186,549	6/1965	Botstiber	210/86

FOREIGN PATENTS OR APPLICATIONS

912,719	12/1962	Great Britain	210/222
272,270	8/1970	U.S.S.R.	55/100

OTHER PUBLICATIONS

German Printed Application No. 1,032,463, printed June 19, 1958, (2 sheets drawing, 2 pages specification), copy in Group 177.

Primary Examiner—Dennis E. Talbert, Jr.
Attorney—V. Alexander Scher et al.

[57] **ABSTRACT**

A separating device for fine particles which comprises a housing provided with an inlet port adapted to intake the engine exhaust gas and an outlet port through which a cleaned exhaust gas is discharged. Within the housing, a magnetic unit having a plurality of magnetic elements is arranged in parallel in the axial direction of the housing with a space from each other to form magnetic fields in each space. The magnetic unit is also spaced from the inner surface of the housing. The space between the magnetic elements forms a part of a gas passage connecting the inlet port to the outlet port of the housing. The fine particles coming to this space are forced away from the space due to the magnetic force therein and cleaned exhaust gas is discharged to the outside of the housing through its outlet port.

6 Claims, 5 Drawing Figures

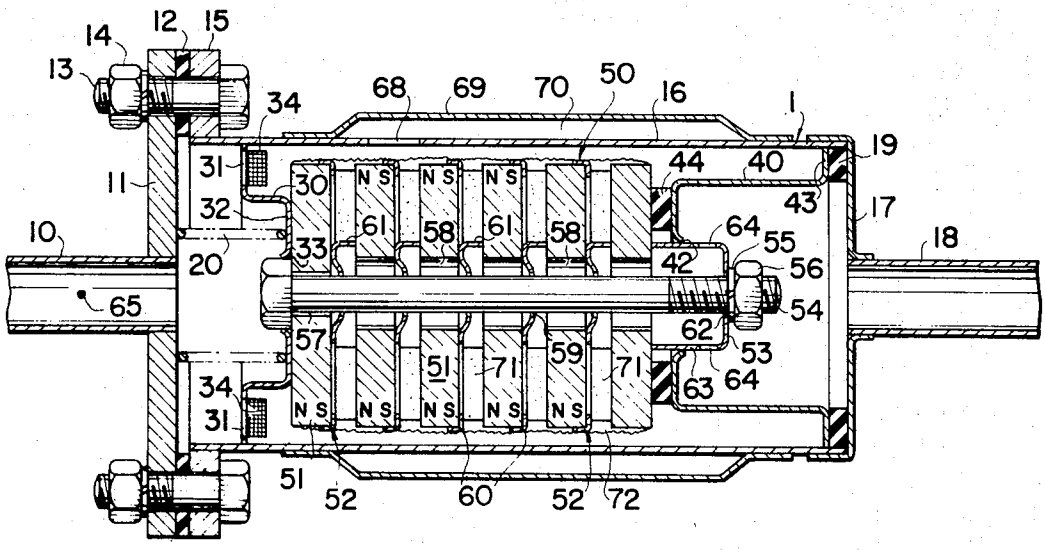


FIG. 1

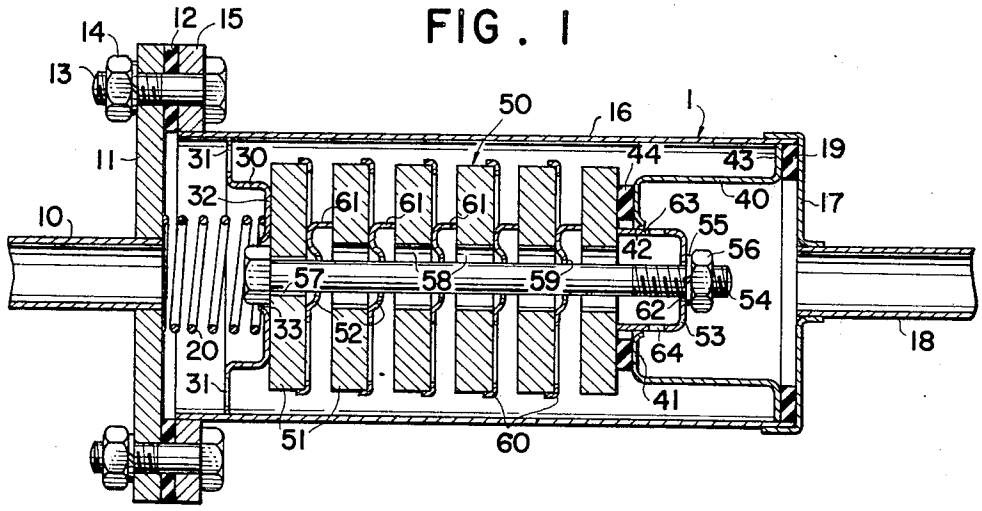


FIG. 2

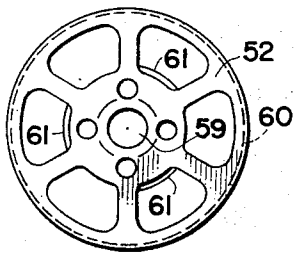


FIG. 3

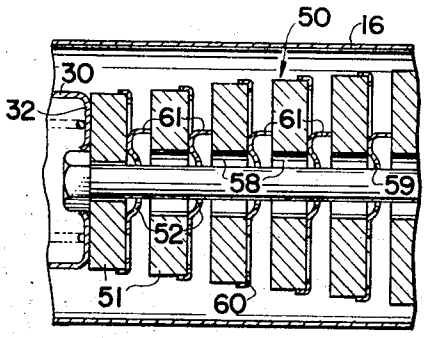


FIG. 4

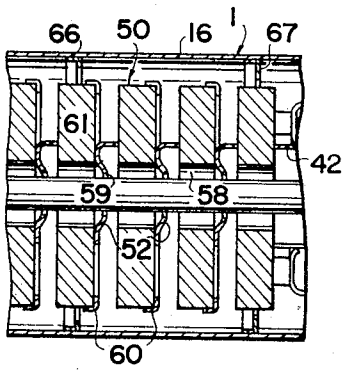
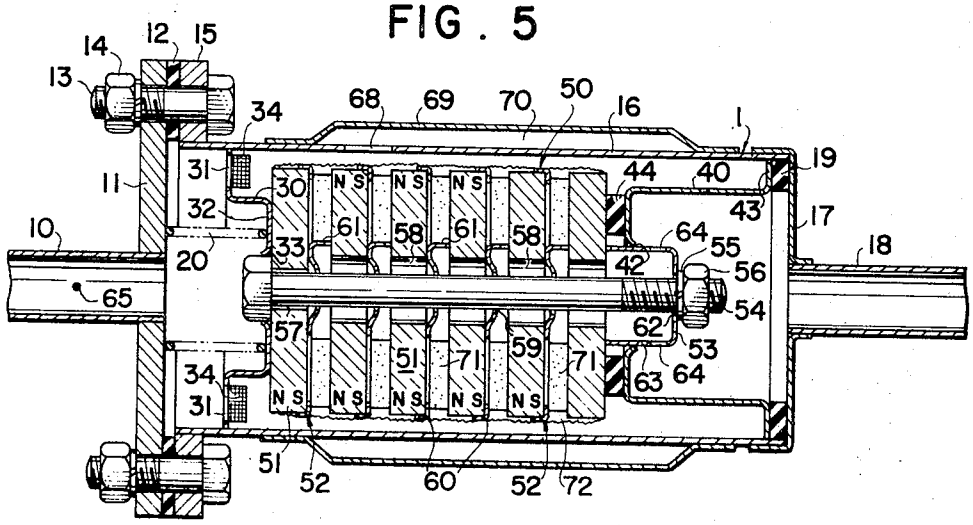


FIG. 5



SEPARATING DEVICE FOR FINE PARTICLES, SUCH AS CARBONS AND THE LIKE

This invention relates to separating devices for fine particles from engine exhaust gas and more particularly to separating devices for carbon, lead compounds, and fine heavy metal particles and other floating fine particles causing air pollution from engine exhaust gas.

It is known that carbon monoxide, hydrocarbon, and oxided nitrogen in the exhaust gas are main substances causing air pollution. It is further known that photochemical reaction, which is generated when ultraviolet rays of sun act upon oxidized nitrogen and hydrocarbon, affects eyes and throat, and causes hypnosis and impediment of eyesight. The amount of carbon monoxide and hydrocarbon can be decreased by raising the combusion efficiency of an engine, while oxidized nitrogen increases as the maximum combusion temperature of the engine is raised. Thus, in a known cleaning device used to reduce oxidized nitrogen, a part of the exhaust gas discharged through an exhaust pipe of the engine is again returned to an intake passage of the engine in a convenient manner so as to reduce the amount of intake oxygen. Thus, lowering the maximum combusion temperature, the creation of nitrogen monoxide (NO) is prevented. In such a cleaning device, a control valve is provided at an inlet through which the exhaust gas is returned into the intake passage. The control valve opens to the exhaust gas when the larger amount of oxidized nitrogen is created under high speed operations of the engine and closes when the smaller amount of oxided nitrogen is created at engine idling. The fine particles such as carbons entrained in the returned exhaust gas have a bad effect on the smooth movement of the control valve and pollute the inside of the engine to hasten wear and tear thereof. Accordingly, it is suggested to remove them from the exhaust gas to be returned.

On the other hand, Diesel engine car running in the city with black exhaust gas discharging from the exhaust pipes will not only difile the appearance of the city but also give uncomfortable feelings to anyone therein. Therefore, recently in many countries, the allowable degree of black of the exhaust gas has been prescribed. To reduce the degree of black, it is usual to separate and collect the soot on the way of exhaust line.

Many technical difficulties have been experienced to remove the carbon particles in the exhaust gas. Normally, the carbon particles comprises fine particles in the range of 0.02–0.04 μ and combined particles of these fine particles in the range of 1–30 μ, so that these carbon particles cannot be effectively removed from the exhaust gas by the conventional filter media. Furthermore, the filter media have to be heat-proof to resist the high temperature in the exhaust line. But, a filter media which will require a higher pressure to pass through is not acceptable.

An object of the present invention is to provide a cleaning device which will safisfy the above-mentioned requirements

Another object of the present invention is to provide a separating device wherein fine particles such as carbons entrained in an exhaust gas and charged with electricity while they are travelling along a combusion system and an exhaust line are fed to a magnetic field and are removed therefrom to be separated from the exhaust gas discharged outside an exhaust pipe.

Another object is to privide a separating device of the described type wherein the fine particles such as carbons in the exhaust gas are further positively charged with electricity to increase the collecting efficiency.

Another object is to provide a separating device wherein the exhaust gas entraining the fine particles charged with electricity is forced to uniformly pass through the magnetic field to reduce the pressure drop therethrough.

Another object is to provide a separating device wherein a magnetic separating unit is combined with a known centrifugal separating unit or a known filter media to provide a better separating efficiency.

Other objects of the present invention will become apparent in the course of the following specification.

This invention is based upon a known phonomenon that an electron (electric charge:—e coulomb) moving vertically with respect to a magnetic field of a fixed valve H gaus at a velocity of v (cm/sec) is given a force f (dyne) as follows:

$$f = 1/10\ \mathrm{Hev}$$

This force acts vertically to the moving direction of the electron, so that, without changing the velocity (v), the electron goes away from the magnetic field along a circular path. As the valve of the magnetic field gets higher, the electron will be thrown away from the magnetic field along the circular path.

The present invention has incorporated this phenomena in a separating device for carbon or other fine particles charged with electricity in an exhaust gas. Accordingly, the conventional disadvantages experienced with the use of the filter media have been eliminated by the present invention.

The invention will appear more clearly from the following detailed description when taken in connection with the accompanying drawing showing by way of example only, preferred embodiments of the inventive idea.

In the drawing:

FIG. **1** is a cross-sectional view showing a separating device according to the present invention;

FIG. **2** is a plane view showing a supporter for a magnetic element;

FIG. **3** is a cross-sectioned view showing main portions of a separating device according to a second embodiment of the present invention, in which magnetic elements becoming larger in their diameters as they go to an outlet port of the device are arranged in parallel;

FIG. **4** is a cross-sectioned view showing main portions of a separating device according to a third embodiment of the present invention, in which baffle plates are provided in the device; and

FIG. **5** is a cross-sectioned view showing a separating device according to a fourth embodiment of the present invention.

Referring now to a separating device according to a first embodiment of the present invention shown in FIG. **1**, a cylindrical body **1** is provided with an inlet conduit **10** and an outlet conduit **18** for engine exhaust gas. The inlet conduit **10** passes through the center portion of a front closure plate **11** and is fixed thereto to allow the engine exhaust gas to enter into the cylindrical body **1**. The closure plate **11** is connected to a cylindrical member **16** by bolts **13** passing through a flange **15** at an open end of the cylindrical member **16** and cramped to nuts **14** at the front circumferential surface

of the closure plate **11** with a gasket **12** interposed between the plate **11** and the flange **15**. The flange **15** is welded to the cylindrical member or may be integral therewith.

Within the cylindrical body **1** a magnetic unit **50** is disposed along the axial direction thereof with a predetermined annular space from the inner surface of the cylindrical member **16**. The magnetic unit **50** is held in its position by a rear retainer cup **40** and a front retainer cup **30**, both being loosely and removably engaged at their circumferential edges with the inner surface of the cylindrical member **16**. The rear retainer cup **40** seats at its outer circumferential edge portions against an annular gasket **19** which is placed on the inner circumferential portions of the rear retainer cup **17**. The rear closure plate **17** has the outlet conduit **18** provided through a central opening thereof.

The front retainer cup **30** receives an end of a compressed spring **20** the other end of which seats upon the rear surface of the front closure plate **11**, so that the front retainer cap **30** slidable along the inner surface of the cylindrical member biasses the magnetic unit **50** toward the rear retainer cup **40**. The front retainer cup **30** is provided at its circumferential portion with a plurality of openings **31** through which gas can pass. The rear end of the magnetic unit **50** is received by the rear retainer cup **40** with an annular gasket **44** interposed therebetween.

The magnetic unit comprises, in the embodiments shown in the drawings, six flat cylindrical magnetic elements **51**, five supporters **52** interposed between each two magnetic members **51** to support them in parallel with a predetermined space, a cap shaped metal member **53**, a bolt **54** passing through the all magnetic elements and supporters, and a nut **56** threaded to the bolt **54** with a washer **55** interposed between it and the cap shaped metal member **53**. The foremost magnetic element **51** has a relatively small central bore **57** so that the bolt **54** passing therethrough may be seated at its head portion to the front surface thereof. The other magnetic elements have a relative large bore **58**, which forms an annular space about the bolt to permit the exhaust gas to pass therethrough.

Each supporter **52** for magnetic element **51** has a small central hole **59** through which the bolt **54** passes, a circumferential flange **60** forwardly folded to snugly receive the outer cylindrical surface of the magnetic element **51**, and three rearwardly folded legs **61** of circular sections the diameters of which are larger than the larger bore **58** of the magnetic element **51** to enable the legs **61** to rest upon the front surface of the adjacent magnetic element and to define a predetermined space between the two adjacent magnetic elements **51**.

The cap-shaped metal member **53** at the rear end of the magnetic unit **50** has a relatively small hole **62** through which the bolt **54** passes. The cap-shaped member **53** also has a plurality of openings formed through its cylindrical wall **63** the diameters of which are substantially the same as those of the legs **61** of the supporters **52**.

In assembly of the magnetic unit **50**, magnetic elements **51** are so arranged that the magnetic pole S in one magnetic element may face the magnetic pole N in the adjacent magentic element with the space determined by the length of the legs **61** of the supporter. Thus, magnetic fields are formed in every space between the magnetic elements. The magnetic element **51** may be a permanent magnet or an electrical magnet, not shown, in which a cylindrical iron member is wound by a conductive wire to apply electric current.

In arranging the magnetic elements **51** in a predetermined parallel spaced relation by the supporters, the bolt **54** is inserted through the aligned bores and holes of the magnetic elements **51** and the supporters **52**, respectively, and is cramped at its rear end passing beyond the cap-shaped metal cap **53** by the nut **56**.

Before assemblying the magnetic unit **50** within the cylindrical body, the rear retainer cup provided with a central opening **42** is disposed within the cylindrical body **1** by interposing the gasket **19** between the circumferential edge portion **43** of the rear retainer cup **40** and the rear closure plate **17**. Then, the cap-shaped metal member **53** of the magnetic unit **50** is inserted through the central opening **42** of the rear retainer cup **40** by interposing the gasket **44** between the rearmost magnet element **51** and rear retainer cup portion which is adjacent the central opening **42**. The front retainer cup **30** permits the head of the bolt **54** to pass through a central hole **33** thereof. Thus, the magnetic unit **50** is prevented from lateral movement by the front and rear retainer cups **30** and **40**. Then, the spring **20** is compressed between the front retainer cup **30** and the front closure plate **11**, so that the front retainer cup **30** urges the magnetic unit **50** toward the rear retainer cup **40** to firmly set the magnetic unit in the cylindrical body under any vibratory conditions. The assembly is completed by cramping the flange **15** of the cylindrical member **16** to the circumferential portions of the front closure plate **11** by the bolts **13** and nuts **14**.

When this separating device is associated with an exhaust line, the exhaust gas enters into the separating device through the inlet conduit **10**. Then, passing through, in turn, the peripheral holes **31** of the front retainer cup **30**, the annular space between the cylindrical member and the magnetic unit **50**, the annular spaces between the magnetic elements **51** forming magnetic fields, a plurality of openings between the rearwardly folded legs **61** of the supporters **52**, the large bores **58** of the magnetic elements **51**, the holes **64** in the cylindrical wall **63** of the cap-shaped metal member **53**, and the outlet conduit **18**, the exhaust gas is discharged outside of the separating device.

Fine particles such as carbon particles entrained in the engine exhaust gas are charged with electricity while they travel through combusion system and discharge line, so that, when they enter into the annular spaces of each pair of adjacent magnetic elements having opposite magnetic poles at their opposing sides, they are effected by the magnetic field in the annular spaces and are forced away from the annular spaces. Thus, the outwardly forced particles are attracted to the inner surface of the cylindrical member **16** and cannot pass through the magnetic field. Only the exhaust gas free from such particles passes through the annular spaces between the magnetic elements **51** and is discharged through the outlet conduit by way of the succeeding passages in the cylindrical body. The exhaust gas coming to the outlet conduit may be again returned to the combusion system to reduce oxidized nitrogen and, especially, nitrogen monoxide or may be directly discharged into the asmosphere.

A test example of the separating device according to the present invention shall be described hereinafter:

Six permanent magnet bodies **51** each having a diameter of 60mm and a thickness of 10mm were spaced in parallel wilh each other at intervals of 3mm and disposed, as shown in FIG. **1**, within the cylinder having an inner diameter of 70mm. The magnetic field in each annular space between the two adjacent magnetic bodies had the value of 1,500 gauss. This separating device was assembled to an exhaust line of 1,800cc gasoline engine which was operated with the use of gasoline not containing lead under the conditions of one-half load and 1,500r.p.m. The exhaust gas of 200 l/min, which amount corresponds to 10–20 percent by volume of the whole exhaust gas, was introduced into the separating device. After continuous operation of the engine for 100 hours, the fine particles of 1.62g were separated from all harmful fine particles of 1.96g in the exhaust gas and attached to the inner surface of the cylindrical member **16,** from which the separated particles were removed. Furthermore, it has been noted that the pressure rise caused by the provision of this separating device was 6mm Aq, which amount is low enough to enable this device to be practically used.

In order to facilitate the electric charge of the fine particles such as carbon and, thereby, to separate them more effectively, preferably, an electrode member **65** is provided within the inlet conduit **10.**

In the first embodiment disclosed above, all magnetic elements **51** have the same, so that the larger amount of exhaust gas entered into the cylindrical body **1** will pass through the annular spaces between the magnetic elements **51** at the side of the inlet conduit **10.**

In a second embodiment of the separating device according to the present invention shown in FIG. **3,** in order to uniformly flow the exhaust gas entered into the cylindrical body **1** through the inlet conduit to each annular space between the magnetic elements **51,** the magnetic elements **51** increase in diameters as they extend from the inlet conduit side to the outlet conduit side.

In a third embodiment of the separating device according to the present invention shown in FIG. **4,** instead of changing the diameters of the magnetic elements **51** as in the second embodiment, baffle plates **66** and **67** each having an opening larger than the diameters of the magnetic elements **51** are fixed to the inner surface of the cylindrical member **16.** The baffle plate **66** at the side of the inlet conduit **10** has an opening larger than that of **67** at the side of the outlet conduit **18.**

In a fourth embodiment of the separating device according to the present invention shown in FIG. **5,** the separating device comprises, in addition to the first embodiment, deflecting blades **34** rearwardly adjacent to the peripheral holes **31** of the front retainer cup **32,** a restricted hole **68** through a part of the cylindrical member **16,** a cylindrical bulge member **69** encircling the cylindrical member **16** with an annular dust chamber **70** therebetween, which chamber communicates with the inside of the cylindrical member **16** through the opening **69,** a sheet-type filter media **72** enclosing the magnetic elements **51,** and a plurality of annular depth-type filter media **71** interposed between the magnetic elements **51.** The sheet-type and depth-type filter media **72** and **71** are made of heat-proof substances such as glass wool or wire net.

The separating device according to the fourth embodiment is so constructed that the exhaust gas entering into the cylindrical body through the peripheral holes **31** of the front retainer cup **30** is forced to spiral flow by means of the deflecting blades **34.** Accordingly, the heavier particles in the exhaust gas come close to the inner surface of the cylindrical member **16** by centrifugal force of the spiral flow and pass through the restricted hole **68** to be collected in the dust chamber **70.** Only the remaining smaller particles which were not caught by the sheet-type filter media **72** can enter into the spaces between the magnetic elements **51,** from where the smaller particles are separated by the effect of magnetic field and the depth-type filter media **71.**

Many modifications and changes in the described embodiments may be made, for example, the sheet-type filter media and depth-type filter media in the fourth embodiment can be eliminated.

What is claimed is:

1. A separating device for fine particles charged with electricity, such as carbons and the like, from an engine exhaust gas, comprising a housing having an inlet port adapted to in-take said engine exhaust gas and an outlet port through which a cleaned exhaust gas is discharged,

a magnetic unit having a plurality of magnetic elements arranged in parallel with a space in between, adjacent magnetic elements having opposite facing magnetic poles to form magnetic fields in said spaces, said space forming a part of the gas passage connecting said inlet port to said outlet port, and

means mounting said magnetic unit within said housing with a space from the inner surface of said housing,

said magnetic unit comprising a plurality of flat cylindrical magnetic elements, a plurality of supporters for said magnetic elements, each of said supporters having circumferentially spaced legs to define an annular space between adjacent magnetic elements, a cap shaped metal member having openings for cleaned exhaust gas and located at the outside of the rearmost magnetic element adjacent said outlet port of said housing, and means interconnecting said magnetic elements, said supporters and said metal member,

whereby fine particles in said exhaust gas entering into said housing through said inlet port and coming into said spaces between said magnetic elements are forced away from said spaces due to the magnetic force therein, while cleaned exhaust gas is discharged to the outside of said housing through said outlet port thereof.

2. A separating device in accordance with claim **1,** wherein said mounting means comprises a front retainer plate having a hole through which said exhaust gas entraining said fine particles is guided around said magnetic unit, said front retainer plate being slidable relatively to the inner surface of said housing, a spring pressing said plate to said magnetic unit, and a rear retainer plate slidable relating to the inner surface of said housing and pressed against the rear end of said housing by said magnetic unit.

3.A separating device in accordance with claim **2,** further comprising deflecting blades located adjacent said hole of said front retainer plate for imparting spiral flow to the exhaust gas passing therethrough, and a dust chamber communicating with said hole of said front retainer plate through a hole in the wall of said housing.

4. A separating device in accordance with claim **1,** wherein said magnetic elements have the same diame-

ters and said separating device further comprises a plurality of baffle plates mounted on the inner surface of said housing and extending in the axial direction thereof with a space therebetween, one of said baffle plates at the side of said inlet port of said housing having an opening which is larger than that of another baffle plate at the side of said outlet port.

5. A separating device in accordance with claim 1, wherein said magnetic elements have larger diameters as they extend toward said outlet port.

6. A separating device as claimed in claim 1, wherein a plurality of filter medias made of glass wool are interposed between said magnetic elements.

* * * * *