(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 599 323 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **93119035.9**

(51) Int. Cl.5: **F01N 3/02**

(22) Date of filing: **25.11.93**

(30) Priority: **26.11.92 IT TO920956**

(43) Date of publication of application:
01.06.94 Bulletin 94/22

(84) Designated Contracting States:
CH DE ES FR GB IT LI SE

(71) Applicant: **IVECO FIAT S.p.A.**
Via Puglia 35
I-10156 Torino(IT)

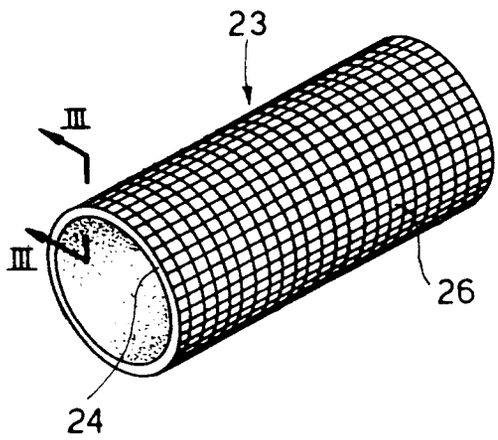
(72) Inventor: **Cuniberti, Francesco**
Via Breglio, 127
I-10100 Torino(IT)
Inventor: **Ouaranta, Sante**
Via Umberto I, 11
I-10040 Riva(IT)

(74) Representative: **Jorio, Paolo et al**
Studio Torta,
Via Viotti, 9
I-10121 Torino (IT)

(54) A regenerable filter for the exhaust gas of an internal-combustion engine.

(57) A filter cartridge (23) comprises a wall (24) formed of a porous and electrically conductive material. Two electrodes (29, 31) of opposite polarity are connected to two parts (32, 33) of the wall (24), which are mutually positioned so that, by supplying electrical energy to the two electrodes (29,31), current is induced to flow along an oblong zone (36) of the wall (24) itself thus bringing about the combustion of the residual products of the combustion of the gas present in said zone (36), and thus initiating the regeneration of the cartridge (23). The porous material is preferably formed of partly sintered and/or catalysed metallic powders or fibres.

Fig. 2



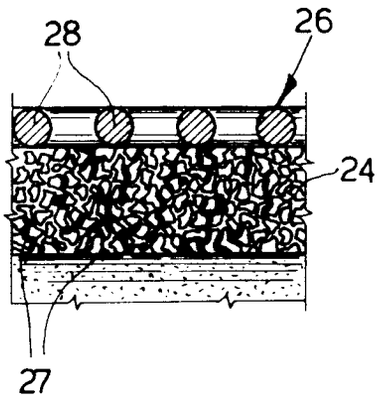


Fig. 3

EP 0 599 323 A1

The present invention relates to a regenerable filter for the exhaust gas of an internal-combustion engine. In particular, the invention relates to a filter which can be disposed along an exhaust pipe of an internal-combustion engine, said filter comprising a filter layer for collecting the residual products of the combustion of the gases, and electrical means which can be actuated to supply electrical energy to the filter layer, so as to initiate the regeneration of the filter itself.

Various types of filters are known, in which said electrical means comprise resistive elements which are excited so as to initiate the regeneration of the filter. In one known type, said resistive elements are disposed upstream of the filter and, when current flows through them, they cause the temperature of the gases to rise by Joule effect, which then act on the filter surface.

This solution involves high consumption of electrical energy, which is associated with the risk of excessive loss of charge from the vehicle's battery. Moreover, the continuity of the filter layer in the various sections can enable extensive and violent combustion to occur. Additionally, since the heating takes place by convection and radiation, the total electrical energy supplied is always considerably greater than that required to initiate locally the combustion of the residues. To overcome these drawbacks filters have been devised which comprise a series of sections which can be regenerated cyclically in sequence.

Filters have also been proposed, in which the filter layer is formed by an electrically resistive material. This layer, which is optionally subdivided into a series of bands, is connected to electrodes so that the electric current flows completely through each band during the respective excitation. These filters have a certain degree of complexity in their construction because of the necessary cutting off of the power supply.

It is the object of the invention to devise a regenerable filter for the exhaust gas of an internal-combustion engine, which is of the utmost simplicity, has the maximum operating reliability and which obviates the above-mentioned disadvantages of known filters.

This object is achieved by the regenerable filter according to the invention, which comprises a filter layer for collecting the residual products of the combustion of said gas, said layer being formed of a porous and electrically conductive material, and electrical means which can be actuated to supply electrical energy to said layer, and is characterised in that said electrical means comprise at least two electrodes of opposite polarity connected to two corresponding parts of said layer and such that, by supplying said energy, current is caused to flow along an oblong zone of said layer disposed between said electrodes, said current being of an intensity such that the temperature is raised so as to induce the combustion of said products in said zone, thus initiating the regeneration of said layer starting from said zone.

With a view to a better understanding of the invention, preferred embodiments thereof will now be described below, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 is a schematic section through a regenerable filter for the exhaust gas of an internal-combustion engine constructed in accordance with the present invention;

Figure 2 is a view in perspective of the filter in Figure 1;

Figure 3 is a section through a part of the filter in Figure 1, on a greatly enlarged scale;

Figures 4, 5 and 6 are views in perspective of a filter layer of the filter in Figure 2, according to the same number of embodiments of the invention;

Figure 7 is a front view of the filter layer in Figure 6;

Figure 8 is a view in perspective of the filter layer of the filter in Figure 2, according to another embodiment of the invention;

Figure 9 is a diagram showing a zone for initiating the regeneration of the filter;

Figures 10 and 11 are two diagrams of two alternative electric circuits used to control the initiation of the regeneration of the filter;

Figure 12 is a section through a filter according to a variant of Figure 2;

Figure 13 is a section through a part of a filter according to a variant of Figure 3;

Figures 14 and 15 are two partial views in perspective of two variants of Figures 4 and 5.

Referring now to Figure 1, the reference numeral 12 generally denotes a filter for the exhaust gas of an internal-combustion engine, which can be mounted in the pipe for said gas in the vicinity of the engine block. The filter 12 comprises a substantially cylindrical outer casing 13 which, at one end, is connected with an inlet pipe 14 and, at the other end, is connected via a frusto-conical zone 15 with an outlet pipe 16.

The casing 13 is provided with an annular solid-wall flange 17 fixed thereto level with the inlet pipe 14. Additionally, the casing 13 is provided with a solid-wall disc 18 carried by a perforated annular flange 19 fixed thereto level with the frusto-conical zone 15. The two flanges 17 and 19 are provided with annular supports 21 and 22 to form a seating which can accommodate a removable filter cartridge 23.

The cartridge 23 (Figure 2) substantially comprises a layer of porous filter material in the form of a substantially tubular wall 24. In particular, the wall

24 (Figures 3 and 13) may comprise a powdered and/or fibre metallic material, optionally partially sintered, so as to cement the metallic particles together only in given microzones 27.

Alternatively, the filter material may be composed of compacted steel filaments. Moreover, there can be added to the material a noble catalytic material, such as platinum, rhodium and the like, which can lower the temperature at which the combustion of the exhaust gas residues is initiated and, therefore, of the regeneration of the filter itself.

In Figure 2 the wall 24 is substantially cylindrical, Alternatively, according to the variant of Figure 12, the wall 24 can be pleated or formed by zones 24' bent in zig-zag fashion, so as increase the transit surface thereof for the exhaust gas, thereby reducing the speed of transit inside the filter material. Optionally, it may be contained in a cylindrical casing (not shown in the drawing).

In any case, the material used should impart to the wall 24 a sufficient degree of permeability to the exhaust gas, electrical resistivity and thermal conductivity within predetermined values. Depending on the consistency of the material of the wall 24, the latter can be supported partly or wholly by a mesh or metal netting 26, as will be explained more precisely below.

In particular, according to the variant of Figure 3, the netting 26 is disposed only on the outer surface of the wall 24 and wholly accommodates the wall 24 on its inside. According to the variant of Figure 13, two coaxial nettings 26 are provided, disposed respectively on the outer surface and inner surface of the wall 24; said solution is necessary when the filter material is composed of said steel filaments to be maintained compacted.

Each netting 26 comprises a series of suitably interwoven metal filaments 28 and exhibits sufficient mechanical strength. Additionally, it makes it possible to graduate the electrical resistance of the wall 24, for example by varying the diameter of the filaments 28 forming the aforementioned mesh.

The exhaust gases, which enter the filter (Figure 2) through the inlet pipe 14, pass through the cartridge 23 thus depositing the so-called particulate, i.e. the solid and aerosol residues of combustion, in the interstices of the wall 24. The exhaust gases filtered in this way, through the wall 26, pass into the annular chamber formed by the casing 13, from where they exit through the exhaust pipe 16. The residues progressively clog the wall 24 and thus reduce its permeability, whereby at intervals it is necessary to regenerate said wall 24 by burning these residues.

According to one feature of the invention, at least two electrodes of opposite polarity 29 and 31 (Figure 9) are connected to two corresponding parts 32 and 33 of the wall 24. The two electrodes 29 and 31 are connected through an electric circuit, which will be described in more detail below, to the poles of a battery 35 (Figures 11 or 12), generally the battery of the motor vehicle, and/or with the onboard electrical generator. By exciting the electrodes 29 and 31 (Figure 9) a flow of current is induced in the wall 24. The current density through the wall 24 is at maximum along the shortest path between the two electrodes 29 and 31 and decreases gradually as the path between said parts increases.

In this way an oblong zone 36 (Figure 9) is defined between the two electrodes 29 and 31, in which said current density is sufficiently high to cause the combustion of the exhaust gas residues to be initiated. However, outside the zone 36, the current density is not sufficient to induce this combustion to be initiated.

The zone 36 is substantially in the form of a strip of the wall 24, which is of a width increasing from each of the parts 32 and 33 towards the centre of the zone 36 itself, following the natural course of the lines of equal current density in the wall 24. In Figure 9, the lines of equal current density in the zone 36 are continuous, whereas the lines of equal current density outside the zone 36 are dashed.

According to the embodiment of Figure 4, the wall 24 has two straight edges 37 and 38 which are parallel to the axis of the cylinder and which are joined together by means of a bar 39 of insulating material. In particular, the two edges 37 and 38 are superimposed on one another and are welded on two opposite surfaces of the bar 39 so as to form a substantially annular section of the wall 24 but which is, in fact, in the form of a convolution of a spiral.

The electrodes 29 and 31 are connected to the parts 32 and 33 which are disposed on two opposite surfaces of the wall 24. The zone 36 is of a width increasing from the two parts 32 and 33 towards the position diametrically opposed to the parts 32 and 33. The parts 32 and 33 can be disposed in adjacent positions to an annular edge 41 of the wall 24, as shown in Figure 4. Advantageously, the edge 41 can be disposed in alignment with the inlet pipe 14 (Figure 1) of the casing 13.

When the electric current flows through the electrodes 29 and 31, the zone 36 rapidly reaches the combustion temperature of the unburnt exhaust gas residues accumulated in the interstices of the wall 24. The combustion of the residues is then initiated in the zone 36; said combustion is propagated successively along the axis of the wall 24. Therefore, even if the flow of electric current through the electrodes 29 and 31 is interrupted, the combustion continues, thereby progressively regenerating the entire filter.

Therefore, it is evident that, to regenerate the filter 23, the electrical energy is required only to raise the temperature of a zone 36 of the wall 24, of limited area and for a reduced time, thereby effecting a considerable reduction in power consumption and an increase in the life of the battery 35 (Figures 10 and 11).

According to the variant of Figure 14, instead of a bar 39 of insulating material extending over the entire length of the edges 37 and 38, an insulating part 39' is provided solely to separate the two end parts 32 and 33 of the zone 36 from one another. In this variant it is intended to reduce the netting, here designated 26', to supporting substantially only the zone 36. However, a similar reduced netting can also be provided for the variant of Figure 4.

According to the embodiment of Figure 5, the edges 37 and 38 of the wall 24 are situated adjacent one another and are separated by a bar 42 of insulating material. The two electrodes 29 and 31 are connected to two parts 32 and 33 disposed on the same surface of the wall 24, in alignment with the straight edges 37 and 38 and the annular edge 41. The initiating zone 36 is here of perfectly annular shape and of a width decreasing towards each part 32 and 33. The initiation and propagation of regeneration are analogous to those in the embodiment of Figure 4.

According to the variant of Figure 15, the bar 42 can be replaced with a part 42' of insulating material, limited to the electrical separation between the two parts 32 and 33, as is the case in Figure 14. In Figure 15 it is also intended to reduce the netting 26' to supporting only the zone 36.

According to the embodiment of Figures 6 and 7, the two straight edges 37 and 38 of the wall 24 are situated adjacent one another and are directly welded together. The two electrodes 29 and 31 are connected to two parts 32 and 33 disposed on the same surface of the wall 24, in two positions diametrically opposite the edge 41.

The initiating zone 36 is here perfectly ring-shaped and has two semi-annular symmetrical strips 36', 36''. Each strip 36', 36'' is of a width decreasing from the centre towards the two parts 32 and 33 of the wall 24. In this case too, the initiating and propagation of regeneration are analogous to those in the embodiment of Figure 4.

According to the embodiment of Figure 8, the two edges 37 and 38 of the wall 24 are situated adjacent one another and are directly welded together, as in the embodiment of Figure 6. One of the two electrodes 29 and 31, for example the positive electrode 29, is connected to a part 43 disposed on the centre line of a generator of the cylinder. However, the other electrode is replaced by two electrodes 44, both of which are supplied by the negative pole of the battery 34. The two electrodes are connected to two parts 46 disposed at the two opposite ends of the same generator of the part 43.

An initiating zone 48, which has two paths 48', 48'' disposed along said generator, is now formed between the electrodes 29 and 44. Each path 48', 48'' is of a width decreasing from the centre towards the part 43 and towards two parts 46 of the wall 24. The initiation of regeneration thus takes place in the zone 48 which extends over the entire length of the wall 24. However, the propagation of the regeneration takes place from the zone 48 proceeding in a circular direction parallel to said generator.

The supply circuit for the electrodes 29, 31 (Figures 4-7, 14 and 15) or 29, 44 (Figure 8) comprises, in addition to said battery 35 (Figures 10 and 11), a switch 49 which is actuated in known manner to control the regeneration of the filter.

According to the embodiment of Figure 10, a thermistor 51 with a positive temperature coefficient (PTC) is disposed in series with the switch 49, the resistivity of which thermistor increases with temperature. The PTC 51 is disposed in the vicinity of the wall 24 so as to assume substantially the temperature of the latter.

When the switch 49 is closed, if the wall 24 is cold, as is the case when the engine is being started, the resistivity of the PTC 51 is low and, therefore, a high electric current flows through the zone 36 or 48 so that, in any case, any residues of the gases are caused to undergo combustion in said zone 36 or 48, thus initiating the regeneration of the filter cartridge 23. However, if the temperature of the wall 24 is high, as is the case when the engine is running at the normal operating condition, the resistivity of the PTC 51 increases and, therefore, a lower electric current flows through the zone 36 or 48, which is sufficient to initiate the regeneration of the filter cartridge 23. In this way the consumption of electrical energy for this initiating procedure is always reduced to the minimum required.

According to the embodiment of Figure 11, in series with the switch 49 there is disposed a second switch 52 which is controlled by a control circuit 53 of the type known as a "chopper". The duty cycle of the chopper circuit 53 is reduced as the temperature detected by a temperature sensor 54 increases. The latter essentially comprises a thermocouple (TC) which can detect the temperature of the wall 24, whereby the chopper circuit 53 is controlled retroactively by the thermocouple 54.

When the temperature of the wall 24 is relatively low, the thermocouple 54 controls the chopper circuit 53 in such a way as to actuate the switch 52, thus causing the electric current to flow through the zone 38 or 48 for a relatively long time.

When the temperature sensed by the thermocouple 54 increases, the signal generated by the thermocouple 54 itself induces a reduction in the duty cycle of the output signal generated by the chopper circuit 53, whereby the electric current flows through the zone 36 or 48 of the wall 24 for a time which on average is less than that previously indicated. In this way, the consumption of electrical energy for initiating the regeneration is always reduced to a minimum.

The advantages of the filters of the invention with respect to the known filters are obvious from the foregoing. Firstly, there is a reduction in the zone 36 or 48 to be excited by means of the power supplied by the battery 35 of the motor vehicle, thus increasing its life. In addition, a gradual regeneration is obtained, thus avoiding overheating of the wall 24 of the filter cartridge 23. Finally, the initiating cycle can be controlled periodically in an automatic manner.

In particular, the use of porous metallic material which is electroconductive and has controlled thermal conduction makes possible:

- a local electric initiating procedure with a reduction in the power and electrical energy used;
- graduation of the permeability and thermal conduction so as to allow the continuation of regeneration of the filter, without any shutting-off of the exhaust gas;
- utilisation of the resistance to oxidisation and of the thermal conductivity of the filter to absorb temperature peaks in the filter without damage, even in the event of accidental switching-off and the resultant overloading with particulate, prior to the subsequent regeneration.

It is evident that various modifications and improvements can be made, without departing from the scope of the claims.

For example, the parts 32 and 33 of the wall 24, in the embodiments of Figures 4-7, 14 and 15, can be arranged in such a way that the zone 36 is in alignment with the centre line of the wall 24. In this case, the propagation of regeneration takes place by advancing in two opposite directions, parallel to the axis of the cylinder of the wall 24.

Moreover, in the embodiment of Figure 8, a single electrode 44 can be provided which is connected to a part 46, whereas the electrode 29 can be connected to the other part 46 disposed at the end of the same generator of the cylinder of the wall 24. The arrangement of the electrodes in Figures 4-8, 14 and 15 may also be applied to the wall 24 in accordance with the variant of Figure 12.

It is also evident that the shape (cylindrical or pleated) of the wall 24 should not be considered to be restrictive.

Claims

1. A regenerable filter for the exhaust gas of an internal-combustion engine, comprising a filter layer (24) for collecting the residual products of the combustion of said gas, said layer (24) being formed of a porous and electrically conductive material, and electrical means (35, 29, 31, 44) which can be actuated to supply electrical energy to said layer (24), characterised in that said electrical means (35, 29, 31, 44) comprise at least two electrodes of opposite polarity connected to two corresponding parts (32, 33; 43, 46) of said layer (24) and such that, by supplying said energy, current is caused to flow along an oblong zone (36, 48) of said layer (24) disposed between said two electrodes (29, 31; 29, 44), said current being of an intensity such that the temperature is raised so as to induce the combustion of said products in said zone (36, 48), thus initiating the regeneration of said layer (24) starting from said zone (36, 48).

2. A filter according to Claim 1, in which said wall (24) is disposed in an outer casing (13) provided with at least one inlet pipe (14) and with an outlet pipe (16), characterised in that said filter layer is in the form of a substantially tubular wall (24) and is accommodated in a seating (19, 21) of said casing (13) substantially coaxial with said pipes (14, 16).

3. A filter according to Claim 2, characterised in that said tubular wall (24) is substantially cylindrical.

4. A filter according to Claim 2, characterised in that said tubular wall (24) is of pleated diametral section, essentially formed by a series of zig-zag portions (24').

5. A filter according to any one of Claims 2 to 4, characterised in that said zone (36) is formed by a substantially annular portion of said wall (24), whereby said regeneration propagates axially along said wall (24).

6. A filter according to Claim 5, characterised in that two end parts (32, 33) of said annular zone (36) are separated by a part (39', 42') of insulating material, said electrodes (29, 31) being connected to said two end parts (32, 33), whereby said zone (36) is developed along the entire circumference of said annular part.

7. A filter according to Claim 5, characterised in that said wall has two straight edges (36, 37)

connected by a bar (39, 42) of insulating material, said electrodes (29, 31) being connected to said two parts (32, 33) of said edges (37, 38), whereby said zone (36) is developed along the entire circumference of said annular part.

8. A filter according to Claim 6 or 7, characterised in that said part (39') or said bar (39) of insulating material is disposed between two opposite surfaces of said edges (37, 38) which are superimposed so as to form a spiral section for said wall (24).

9. A filter according to Claim 6 or 7, characterised in that said part (42') or said bar (42) of insulating material is disposed between said edges (37, 38) of said wall (24) and that said electrodes (29, 31) are connected on the same surface of said wall (24).

10. A filter according to Claim 3 or 4, characterised in that said electrodes (29, 31) are connected to two diametrically opposite parts (32, 33) of said annular part, whereby said zone (36) is developed along two half-circumferences (36', 36'') of said annular part.

11. A filter according to any one of Claims 2 to 10, characterised in that said zone (36) is disposed on an annular edge (41) of said wall (24) adjacent said inlet pipe (14).

12. A filter according to any one of Claims 2 to 4, characterised in that said electrodes (29, 44) are disposed along the same generator of said wall (24), whereby said regeneration propagates circumferentially on said wall (24).

13. A filter according to Claim 12, characterised in that an electrode (29) of predetermined polarity is disposed on a central part (43) of said generator, whereas two electrodes (44) of opposite polarity to said predetermined polarity are disposed on two end parts (46) of said generator, said zone (48) being formed by two segments (48', 48'') which are developed in opposite directions along said generator.

14. A filter according to any one of the preceding Claims, characterised in that said filter layer (24) is composed of a powdered or fibre metallic material which is compacted in such a way as to form a structure which is gas-permeable and is electrically conductive.

15. A filter according to Claim 15, characterised in that said material is partially sintered so as to form a spongy structure having a series of micro-zones (27) which cement together the particles of said material.

16. A filter according to Claim 14, characterised in that said material is formed from steel filaments.

17. A filter according to Claim 5 and any one of Claims 14 to 16, characterised in that said material is supported at least at the level of said zone (36) by a metal netting (26, 26') which can graduate the electric resistance and mechanical strength of said zone (24).

18. A filter according to Claim 17, characterised in that said metal netting (26) entirely covers the outer surface of said wall (24).

19. A filter according to Claim 17, characterised in that the inner surface and the outer surface of said wall (24) are supported by two coaxial metal nettings (26).

20. A filter according to any one of the preceding Claims, characterised in that said electrodes (29, 31; 29, 44) are actuated under the control of an intermittent control element (51, 54) which is sensitive to the pressure of said exhaust gas and/or to the temperature of said wall (24).

21. A filter according to Claim 20, characterised in that said control element comprises a thermistor (51) with a positive temperature coefficient which can sense said temperature and is disposed in series with said electrodes (29, 31; 29, 44).

22. A filter according to Claim 20, characterised in that said control element comprises a thermocouple (54) which can sense said temperature and control retroactively a chopper circuit (53) for controlling the regeneration.

23. A filter according to any one of the preceding Claims, characterised by comprising a catalyst material added to said porous and electrically conductive material forming said layer (24), said catalyst material being able to lower the temperature at which the combustion of said residual products is initiated.

Fig.1

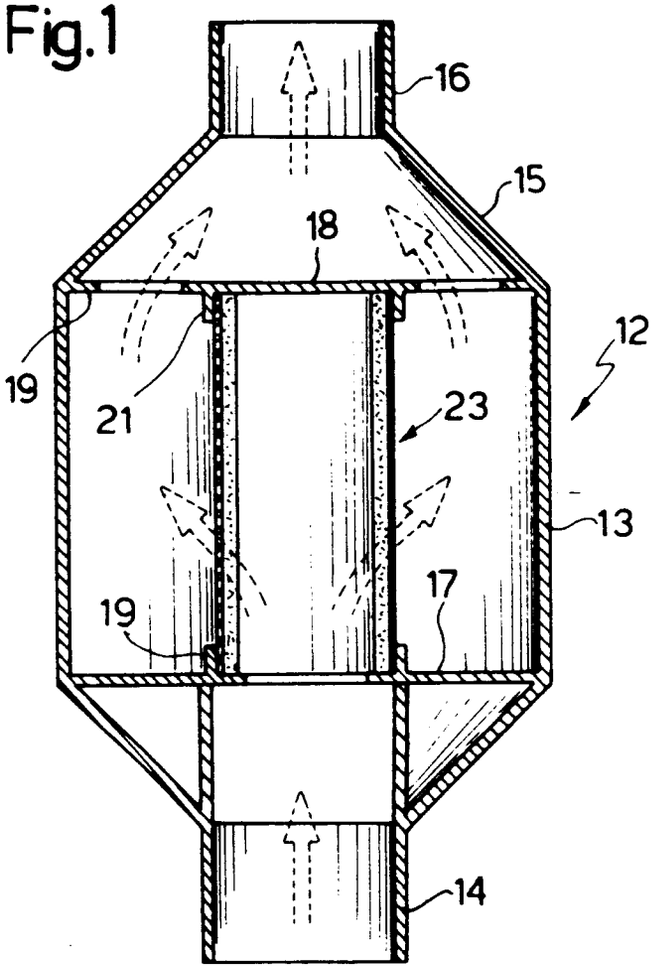
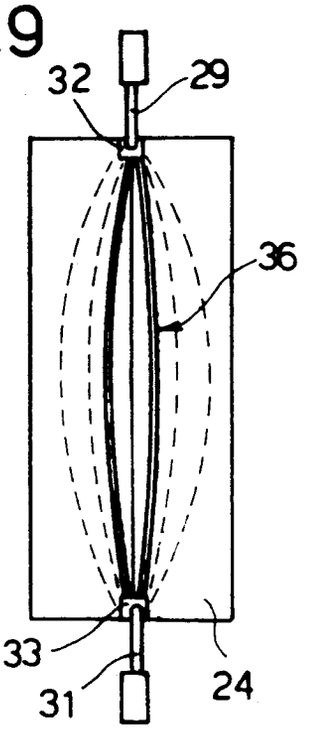


Fig.9



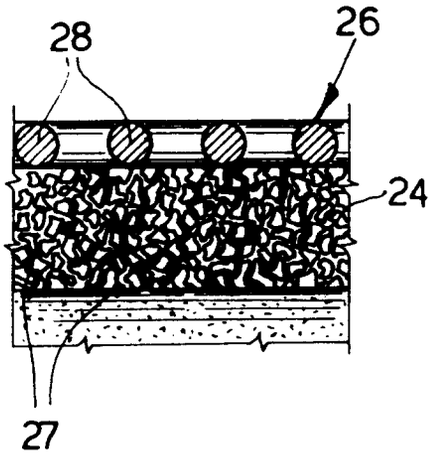


Fig. 2

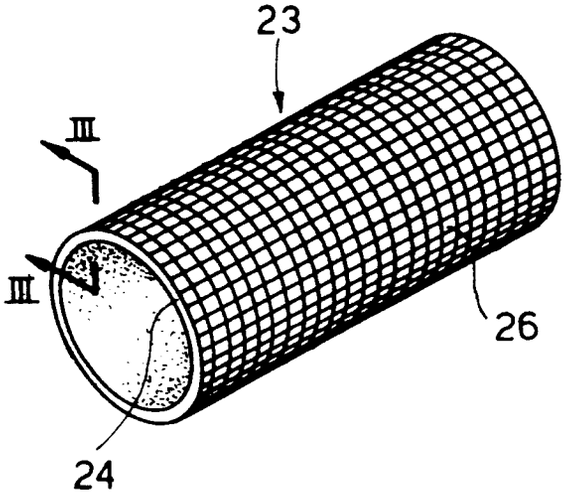


Fig. 3

Fig. 4

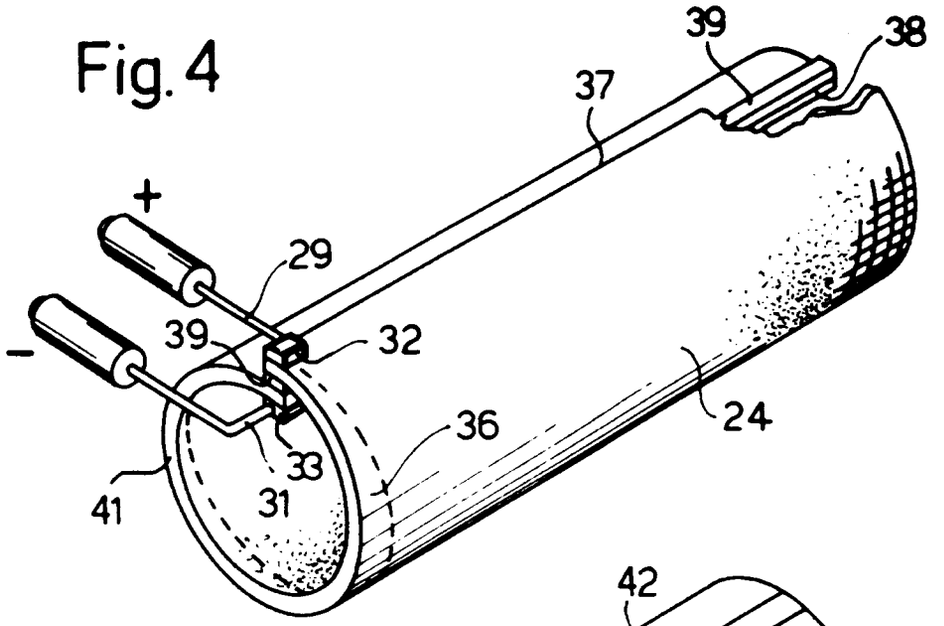


Fig. 5

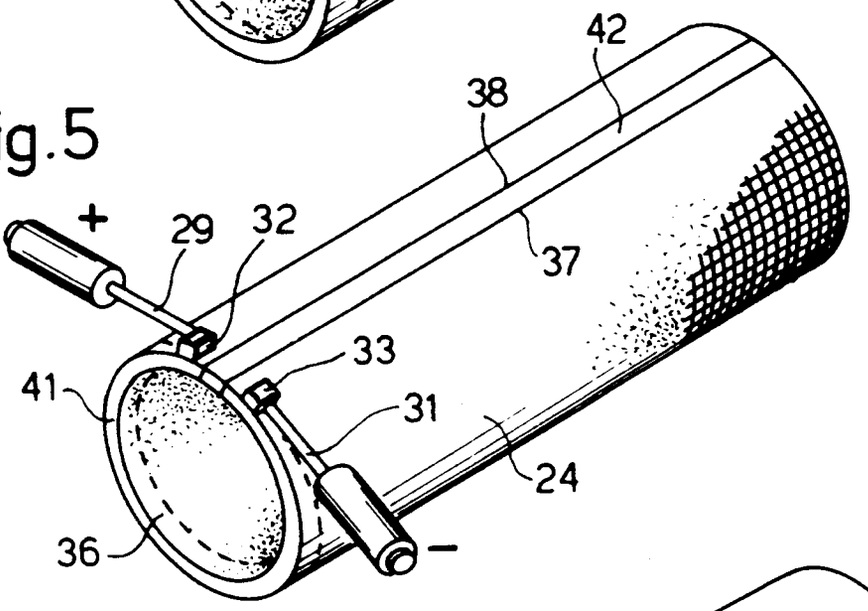


Fig. 6

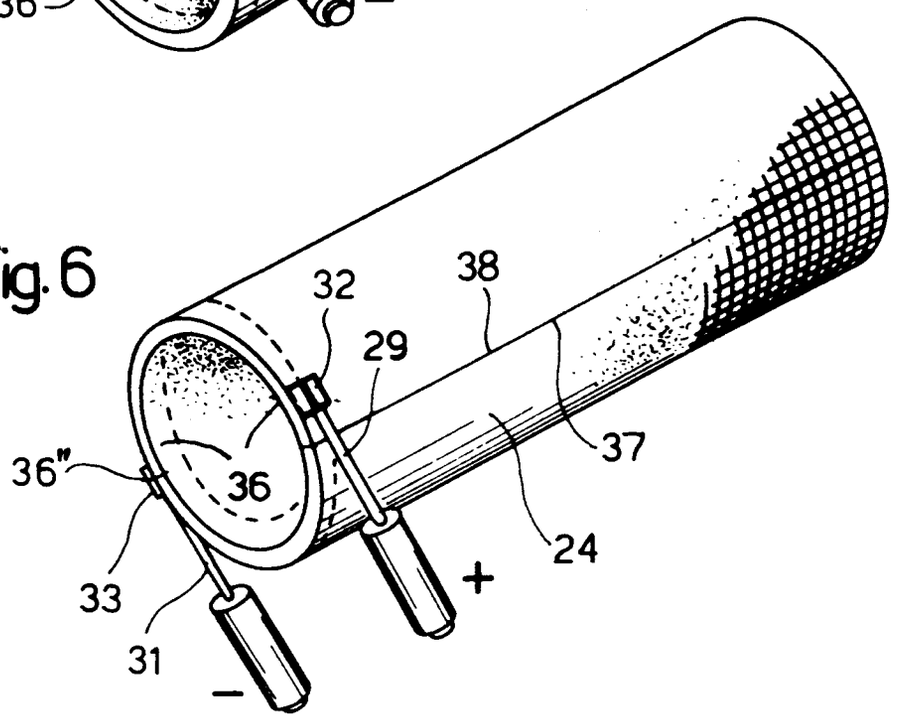


Fig. 7

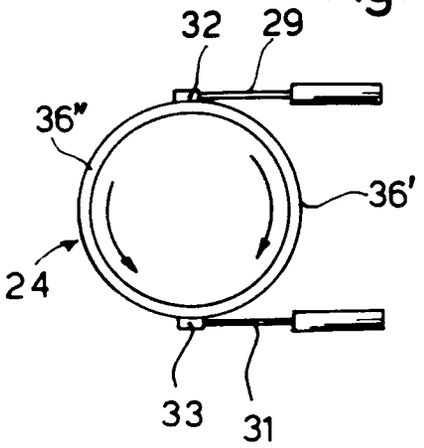


Fig.8

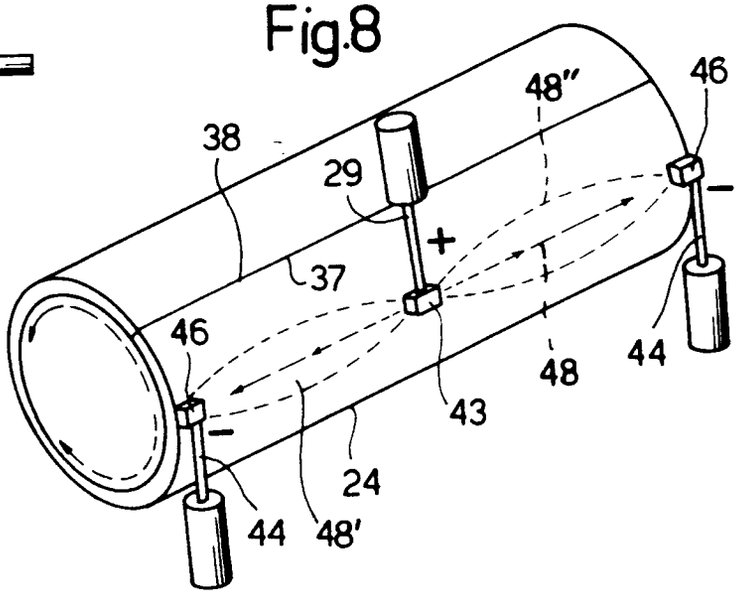


Fig. 10

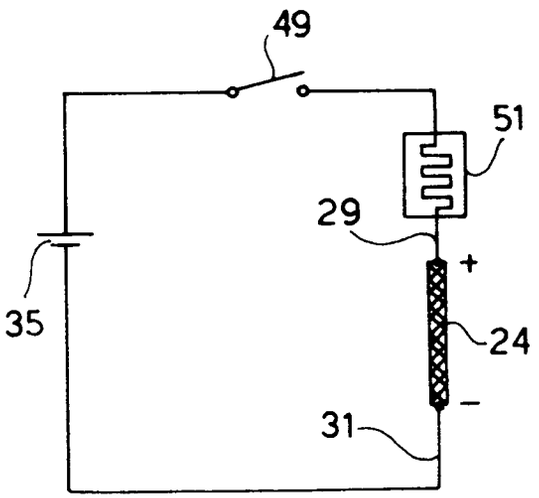
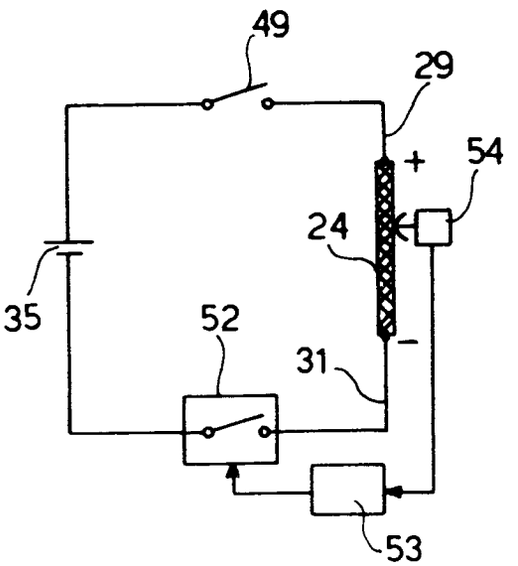


Fig. 11



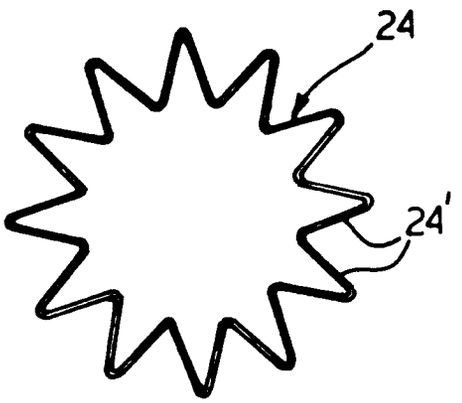


Fig. 12

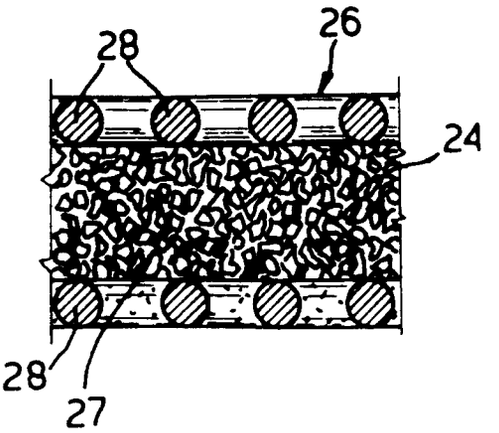


Fig. 13

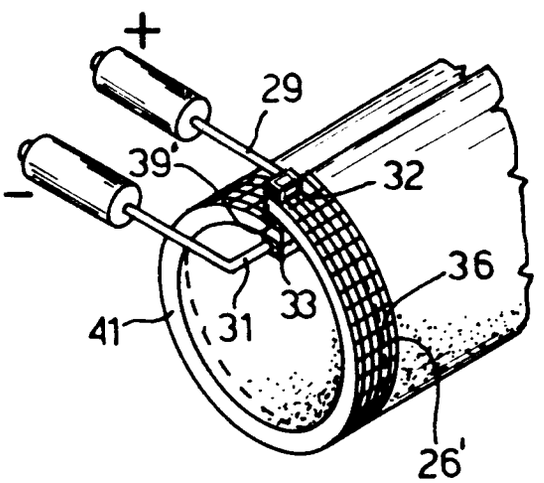


Fig. 14

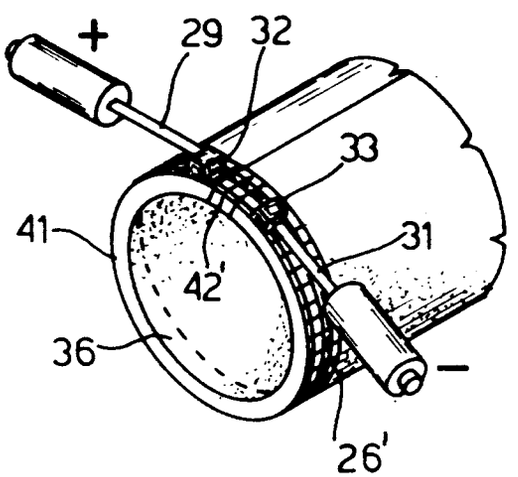


Fig. 15

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 11 9035

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X Y	EP-A-0 382 704 (COCKERILL MECHANICAL INDUSTRIES) * column 5, line 51 - column 8, line 12; figures 2,3 *	1-3,12, 20 14,15	F01N3/02
Y A	EP-A-0 275 372 (KANTHAL GMBH) * column 8, line 3 - line 18; figure 15 *	14,15 1-3,16	
X A	EP-A-0 270 990 (IVECO FIAT) * page 6, paragraph 2 - page 17, last paragraph; figures 1-7 *	1-3,20, 23 4	
X	EP-A-0 244 061 (POROUS ELEMENT HEATING) * column 2, line 47 - column 9, line 30; figures 1-4 *	1-3,20, 23	
A	EP-A-0 504 422 (NIPPONDENSO) * column 4, line 15 - line 34 * * column 6, line 9 - line 49; figures 5,7,8 *	1,14,15, 17	
A	EP-A-0 505 832 (SCHWAEBISCHE HUETTENWERKE)		

TECHNICAL FIELDS SEARCHED (Int.Cl.5)
F01N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 February 1994	Friden, C

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)