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

(11) **EP 3 204 164 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
07.07.2021 Bulletin 2021/27

(21) Application number: **15798543.3**

(22) Date of filing: **08.10.2015**

(51) Int Cl.:
B03C 3/08 *(2006.01)* ***B03C 3/12*** *(2006.01)*
B03C 3/36 *(2006.01)* ***B03C 3/41*** *(2006.01)*
B03C 3/47 *(2006.01)* ***B03C 3/86*** *(2006.01)*

(86) International application number:
PCT/IB2015/001862

(87) International publication number:
WO 2016/055850 (14.04.2016 Gazette 2016/15)

(54) **ELECTROSTATIC FILTER FOR PURIFYING A GAS FLOW**

ELEKTROSTATISCHER FILTER ZUR REINIGUNG EINES GASSTROMS

FILTRE ÉLECTROSTATIQUE POUR PURIFIER UN ÉCOULEMENT DE GAZ

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **08.10.2014 IT PD20140261**

(43) Date of publication of application:
16.08.2017 Bulletin 2017/33

(73) Proprietor: **Sic S.r.l.**
37044 Cologna Veneta (VR) (IT)

(72) Inventors:
- **ALOTTO, Piergiorgio**
I-35027 Noventa Padovana (PD) (IT)
- **BUSELLATO, Marco**
I-36076 Recoaro Terme (VI) (IT)
- **MANTOVANI, Andrea**
I-37047 San Bonifacio (VR) (IT)
- **MERTENS, Daniel**
I-36051 Creazzo (VI) (IT)

(74) Representative: **Gallo, Luca**
Gallo & Partners S.r.l.
Via Rezzonico, 6
35131 Padova (IT)

(56) References cited:
EP-A1- 1 946 845 **EP-A1- 2 246 117**
EP-A1- 2 253 381 **US-A- 4 349 359**
US-A1- 2003 005 824 **US-A1- 2005 150 384**

Printed by Jouve, 75001 PARIS (FR)

Description

Field of application

[0001] The present invention regards an electrostatic filter for purifying a flow of gas and in particular air, according to the preamble of the main independent claim.

[0002] The electrostatic filter, object of the present invention, is intended to be advantageously employed for removing, from a flow of gas or of a mixture of gases, such as air, suspended particles, whether these are constituted by inorganic material, fibers or even biological substances such as bacteria, molds, fungi, spores, viruses etc.

[0003] The present electrostatic filter can be intended for multiple applications both in industrial and civil field; it can for example be employed in the civil field for purifying the air of residential buildings, or in industrial field in order to limit the levels of pollution by filtering the air expelled from production sites, or for treating gaseous flows of industrial processes. For such purpose, the filter, object of the present invention, can be incorporated in a device for domestic use, or in an industrial plant of a production process.

[0004] The present invention is therefore generally inserted in the field of production of apparatuses for removing pollutants from gaseous flows.

State of the art

[0005] Various types of apparatuses are known for removing suspended solid particulate from gaseous fluids; suspended solid particulate is defined as the set of solid and liquid particles with diameter smaller than 100 μm that remain in suspension in the air, including mechanical precipitators (such as cyclones), mechanical filters (such as hose filters) and electrostatic filters.

[0006] The functioning principle of the latter provides for charging the particles suspended in the gaseous flow subjected to filtration, usually due to ionization caused by high voltages over filaments or networks of small-diameter filaments, and their subsequent capture on plates power supplied (or not) at a different potential, towards which the particles are directed by forces of Coulomb type produced by the electric field. Such principle therefore provides for the generation of an ionization field, susceptible of generating a flow of charges that charge the particles in suspension, and of an electric field susceptible of pushing the charged suspended particles towards at least one capture plate at a different potential with respect to the charged particles.

[0007] The electrostatic filters are generally obtained in two different configurations, i.e.: the single-stage filters, in which the ionization electrodes for charging the particles are arranged in the space that separates the capture plates, hence being situated in the electric field susceptible of determining the capture of the particles; and the two-stage filters, in which the capture field is obtained from electrodes of different form and power supply with respect to the field responsible for the ionization.

[0008] Usually, in accordance with the prior art, such configuration of electrostatic filter provides that the first stage, responsible for loading the particles, is constituted by a filament that is transversely crossed by the air flow, and that the second stage is instead constituted by parallel plates arranged longitudinal to the air flow, for example alternately placed at zero potential and at a potential with the same sign as that applied on the electrode in the first stage, so as to repel the loaded particles towards the capture plates with opposite sign. Hereinbelow, several considerations are reported of general character, *per se* known, in order to better understand the operation of the electrostatic filter.

[0009] As is known, in pure gases in standard conditions, there are no free charges and hence they can be considered insulators. When the electric field due to the potential between the electrodes becomes sufficiently high, the gas is ionized and suddenly becomes conductive, attaining the so-called electric breakdown or gas discharge phenomenon.

[0010] This phenomenon is verified both by charging the filiform electrode with positive potential, and with negative potential, but the ionization mechanisms follow different dynamics in both cases. In the present invention, the claimed application takes under consideration electrodes charged with positive potential, generating lower concentrations of ozone in case of air filtration. In such condition, the atoms and molecules close to the electrode, previously neutral, lose electrons, becoming positive.

[0011] In the case of very high field, the charges (hereinbelow, the term charges will indicate electrons and ions, not to be confused with the term particles which are those to be captured, suspended in the air), present in the area of the electrode, are accelerated to speeds such to cause the emission of further electrons and ions in the collision with other atoms or molecules, without losses of kinetic energy. The phenomenon occurs in a very thin layer around the electrode at high voltage, and proceeds in the creation of increasingly more charges which form a "crown" around the filiform electrode, even physically visible in the form of a weak bluish luminescence. In fact, the collisions between the electrons, gas molecules and positive ions produce the emission of light photons with specific wavelength, which in turn generates free electrons, thus participating in the ionization of the gas. An electric current is established between the plate at zero potential (grounded) and the filiform electrode (such current measurable in microamperes), as a function of the potential difference between the electrode and the grounded plate as well as of the environmental conditions. These environmental conditions actually affect the dielectric rigidity of the air, which in turn will have an impact on the intensity of the current made possible by the crown effect, which passes into the ionized air. With the increase of the voltage, the ionization is accentuated and an "avalanche effect" is set off, which leads to making the ionized gas sufficiently conductive to allow, at a specific moment, an actual short-circuit: the intensity of the current thus increases quite rapidly, causing an electric arc discharge. This phenomenon is harmful both due to the ozone that is generated in the air and due to the peaks of current detrimental for the electronics that are part of the filter power supply; such current peaks are of course to be avoided in electrostatic filters.

[0012] With the high-voltage power supply of the electrode present in the filter, but with an ionization current that is lower than that of the preceding discharge case, it is possible to maintain a stable crown effect, which produces a cloud of ions, which will saturate the space comprised between the ionization electrode and the grounded plate, thus charging the particulate contained in the flow of air that traverses the filter.

[0013] By supplying the electrode with direct positive voltage, the free electrons generated in the ionized layer are attracted towards the surface of the electrode, while the positive ions are repelled towards the plates at zero potential. The high speed of the electrons in the zone close to the electrode, and the consequent avalanche effect that is easily formed on the surface of the electrode, facilitate the attainment of the limit condition which brings the field to trigger the crown effect. Consequently, gaseous ions are produced, and an ionization current is attained.

[0014] Of particular importance for the performances of the electrostatic filter is the role of the particle capture process - for capturing the particles which have been charged due to the charges emitted in the ionization stage.

[0015] More in detail, the charges exiting from the ionization stage are repelled in the capture stage by the electric field in the direction of the collection plates, usually at zero potential. The charges in the inter-electrode space collide with the particles suspended in the transiting air flow, and are charged by these particles, creating charged particles subjected to the action of the present field which tends to repel them towards the collection plates.

[0016] The original charge, along with the charge imparted by an ion, is not sufficient for ensuring an effective separation of the particles from the gas. Nevertheless, the particles can collect numerous ions; the particles being able to form an electric field capable of deflecting the original field lines. In such case, this is termed saturation charge, which increases with the particle size; in other words, notwithstanding the greater inertia, large particles can house greater charge and are thus subjected to higher forces (and efficiency). The described phenomenon takes the name "field charging".

[0017] The ions, being charged, precisely follow the force lines due to the electric field, except for the collisions with the gas molecules.

[0018] The presence of a particle in the inter-electrode space causes a deflection of the field lines in proximity to the particle itself, with a consequent increase of the electric field on its surface. The distortion increases with the increase of conductivity (and decreases of the dielectric constant) of the particle. Therefore, all the charges present within field lines incident on the particle will fall thereon and will contribute to its overall charge, determining Coulomb forces on the particle towards the capture electrode.

[0019] In an electrostatic filter, the capture of the particles occurs due to the phenomenon of field charging as well as due to the phenomenon of so-called "diffusion charging".

[0020] With the decrease of the particle diameter, the effect of the field charging is reduced and the main charge process is now due to the thermal agitation motion of the ions, which can bring them to collide with particles, transferring (or better yet sharing) their own charge. Given that it is governed by the kinetic and thermal state of the ions, no electric field is required for the diffusion charging mechanism; a possible electric field only acts as a support. As in the mechanism of field charging, with the accumulation of the charge on a particle, this tends to repel further charges, also giving rise this case to a kind of saturation charge which, however - unlike the preceding case - is logarithmically attained.

[0021] In an electrostatic filter, the mechanisms for charging the particles coexist: while the field charging prevails in the case of particles with diameter greater than 0.5-1.0 μm, the diffusion charging is the predominant mechanism for charging particles with diameter smaller than 0.1-0.2 μm.

[0022] The capture of the charged particles that are still suspended in the gas is the second essential step of the filtration process. To ensure the motion of such particles, the following are present: the turbulent motion of the gas (on its own, it would have a small effect) and an electrostatic field capable of applying a force of Coulomb type.

[0023] In the preferred case, of interest for the present invention, i.e. for filters mainly intended for air-cleaning, positive DC power supply is the most recommended for the lowest production of ozone physically possible with the containment of the electrons in the ionized layer and the lowest capacity of the positive ions to trigger reactions typical of ionization.

[0024] The ozone generation is mainly determined from the equilibrium of the following reactions:

1.

$$e + O_2 \rightarrow 2O + e$$

2.

$$O + O_2 + M \rightarrow O3 + M$$

3.

$$O + O3 \rightarrow 2O_2$$

4.

$$e + O_3 \rightarrow O + O_2 + e$$

where in particular the symbol M in the second reaction indicates a third molecule (e.g. present in the atmosphere, such as N_2 or O_2), which transports away the excess energy and allows the ozone to remain intact; where the symbol "e" indicates the elementary charge of the electron.

[0025] Numerous studies have been conducted for estimating the dependence of ozone generation in electrostatic precipitators based on geometric parameters such as the diameter, shape, roughness and material of the electrode, environmental parameters (such as the temperature of the gas, humidity), fluid-dynamic parameters (such as the speed of the gas flow), electrical parameters, filter operation time, on the load of filtered air, on the state of the electrodes, and on the concentration of ozone naturally present in the environment.

[0026] Up to now, notwithstanding the numerous experiments conducted throughout the world, an analytical-theoretical relation capable of predicting the ozone production starting from geometric, electrical and environmental parameters does not exist. The same numeric instruments capable of simulating plasma physics require information that is often unavailable, and are unable to lead to a result, which is also moreover difficult to measure and compare.

[0027] Hence, the electrostatic filters present on the market do not contemplate an effective regulation of the filter operation parameters, adapted to avoid the onset of dangerous conditions due to the ozone emission; i.e. likewise, they do not provide for the possibility of an optimized operation, given the need to always maintain a safety margin.

[0028] One drawback of the electrostatic filters of known type lies in the fact that the high voltages supplied to the electrodes, by ionizing the air, give rise to reactions that produce undesired gases, and in particular ozone.

[0029] High concentrations of the latter gas are well-known to be dangerous for human beings as well as for the environment, and numerous laws provide for increasingly stringent introduction constraints.

[0030] On the other hand, high voltages are required for increasing the ionization of the particles in the first stage and the repulsion force to which such particles are subjected in the second stage.

[0031] A further drawback lies in the space required for housing the two stages, which involves rather large bulk. On the other hand, the reduction of the size of the plates, e.g. of the charged repulsion plates and of the collection plates of the second stage, up to now appears to lead to lowered filter performances.

[0032] An electrostatic filter is known from the patent US 3,664,092, for purifying a gas, or a mixture of gases, flowing inside the electrostatic filter itself and containing impurities. The electrostatic filter is provided with two electrodes at zero potential in perforated plate form, between which a negative electrode in perforated plate form is interposed. The electrodes are arranged orthogonal to the flow of the gas to be purified.

[0033] A two-stage electrostatic filter is also known from patent WO 01/64349, for purifying a gas, or a mixture of gases, flowing inside the electrostatic filter itself and containing impurities. The electrostatic filter comprises a first ionization stage of the impurities contained in the gas, or in the mixture of gases, and a second stage of precipitation of the impurities. The first ionization stage is provided with at least one negative ionization with needle form, facing an electrode with zero potential in perforated plate or grating form. The electrodes of the first ionization stage are arranged orthogonal to the flow of the gas to be purified.

[0034] The second precipitation stage is provided with at least one negatively-charged repulsion plate, facing at least one capture plate at zero potential. The repulsion plate and the capture plate of the second precipitation stage are arranged parallel to the flow of the gas to be purified.

[0035] The patent US 2005/150384 describes an electrostatic filter of known type comprising a capture stage placed to intercept a gas flow and provided with multiple repulsion electrodes and with multiple collection electrodes parallel to each other, and power supply means adapted to charge each repulsion electrode to a negative potential with respect to the collection electrodes.

[0036] In particular, the collection electrodes of the electrostatic filter are provided with sharp protuberances adapted to create, in the gas flow, turbulence zones and settling zones where the impurity particles suspended in the gas flow itself are accumulated.

[0037] In addition, the repulsion electrodes are provided with openings arranged facing the protuberances of the adjacent collection electrodes, and adapted to facilitate a turbulent motion of the air flow and to avoid the formation of an excessive increase of the electric field at the edges of the protuberances of the collection electrodes.

[0038] However, also the latter solution of known type has drawbacks due to the non-optimal performances and to a high structural complexity.

Presentation of the invention

[0039] In this situation the problem underlying the present invention is therefore that of eliminating the problems of the abovementioned prior art, by providing an electrostatic filter for purifying a flow of gas and in particular air, which is capable of removing high quantities of particles from the gas flow, with high efficiency.

[0040] This is obtained by an electrostatic filter comprising: at least one capture stage provided with at least one plate-like repulsion electrode and with at least one plate-like collection electrode, parallel to each other and arranged for intercepting a gas flow susceptible of proceeding in an advancement direction parallel to the electrodes; power supply means adapted to charge the plate-like repulsion electrode to a positive potential with respect to the plate-like collection electrode, determining an electric field between the electrodes. The plate-like repulsion electrode is provided with a plurality of holes distributed on its surface, whose edges of connection with its two faces have radii of curvature with localized concentrations of the electric field, with consequent emission of positive electric charges in the gas flow, and has a solid over void ratio, due to the plurality of the holes, comprised between 2 and 5. The plate-like repulsion electrodes and the plate-like collection electrodes have flat form, and the plate-like repulsion electrodes delimit, with the plate-like collection electrodes, passage channels which are extended along an extension direction thereof with constant thickness, and through such passage channels the gas flow is susceptible of passing with the advancement direction parallel to the extension direction of the passage channels.

[0041] Another object of the present invention is to provide an electrostatic filter for purifying a flow of gas and in particular air, which is capable of removing the particles with a high energy efficiency.

[0042] Another object of the present invention is to provide an electrostatic filter for purifying a flow of gas and in particular air, which is entirely safe for the environment and for man, releasing zero ozone or in any case very low amounts of ozone.

[0043] Another object of the present invention is to provide an electrostatic filter for purifying a flow of gas and in particular air, which is simple and inexpensive to make and entirely reliable in operation.

[0044] Another object of the present invention is to provide an electrostatic filter for purifying a flow of gas and in particular air, which allows being employed in a versatile manner in different application settings, both for industrial processes and for apparatuses for civil use, such as for sanitizing the air of airflow ducts.

[0045] Another object of the present invention is to provide an electrostatic filter for purifying a flow of gas and in particular air, which is capable of automatically maintaining the optimal operating conditions.

[0046] Another object of the present invention is to provide an electrostatic filter, single or multiple stage, for purifying a flow of gas and in particular air, which is provided with a specific stage for eliminating the ozone, without causing load losses greater than those due to a stage constituted by capture and repulsion plates.

Brief description of the drawings

[0047] The technical characteristics of the invention, according to the aforesaid objects, can be clearly found in the contents of the below-reported claims, and the advantages thereof will be clearer in the following detailed description, made with reference to the enclosed drawings, which represent several merely exemplifying and non-limiting embodiments of the invention, in which:

- figure 1 schematically shows the electrostatic filter, object of the present invention, in a first perspective view and in accordance with a possible embodiment thereof of two-stage type;
- figure 2 schematically shows an enlarged portion of the electrostatic filter of figure 1, object of the present invention, in a second perspective view;
- figure 3A schematically shows the electrostatic filter, object of the present invention, in a third perspective view, with some parts in exploded view in order to better indicate other parts;
- figure 3B schematically shows a second embodiment of the electrostatic filter, object of the present invention, relative to a filter of single-stage type, with some parts in exploded view in order to better indicate other parts;
- figure 3C shows the electrostatic filter of single-stage type of figure 3B in assembled condition;
- figure 3D shows the electrostatic filter of single-stage type of figure 3B, with the succession of plates schematically indicated;
- figures 4 and 5 show two different lateral perspective views of a portion of the filter of figure 1, object of the present invention, in which the means for supporting the different electrodes are visible and in with the perimeter edges are

made in serrated form;

- figure 6A shows a detail of the electrostatic filter, object of the present invention, relative to a perforated repulsion plate advantageously of the filter of two-stage type;
- figure 6B shows a detail of the electrostatic filter, object of the present invention, relative to a perforated repulsion plate advantageously of the filter of single-stage type;
- figure 7 shows an enlarged portion of the perforated repulsion plate of figure 6;
- figure 8 shows the circuit diagram of provided power supply means of the electrodes of the electrostatic filter, object of the present invention.

Detailed description of a preferred embodiment

[0048] With reference to the enclosed drawings, an embodiment of an electrostatic filter, object of the present invention, is indicated with the reference number 1 in its entirety, such filter being susceptible of purifying a gaseous flow indicated with F.

[0049] The electrostatic filter 1, according to the invention, is adapted to be employed for purifying gaseous fluids, such as in particular air, removing contaminant particles from such fluids that are suspended therein.

[0050] Hereinbelow, the term particles will generically indicate any contaminant present in a gaseous fluid F to be treated, which are capable first of being associated with charges and then being affected by the presence of an electric field.

[0051] The contaminant particles will therefore comprise not only inorganic material and fibers, but also biological substances such as bacteria, molds, fungi, bacteria spores, fungus spores etc., hence both micro-pollutant substances in general and organic substances. The particles can have an intrinsic electric charge as well as be susceptible of being associated, in the filter 1, with a charge, before then being affected by an electric field as indicated hereinbelow.

[0052] The particular embodiment illustrated in the enclosed figures 1, 2, 3A relates to a filter of two-stage type; nevertheless, without departing from the protective scope of the present patent, the electrostatic filter 1 according to the present invention can also be obtained with a filter of single-stage type (of which only the overall view of figure 3B is provided) or of the type with at least three stages (three-stage or multi-stage), whose characteristics will be clarified hereinbelow.

[0053] In the preferred but non-limiting embodiment of the enclosed figures 2, 3A of two-stage type, as will be understood hereinbelow, a final stage S3 for removing the ozone is absent.

[0054] It is specified here in advance, for the sake of clarity, that in the electrostatic filter 1 of single-stage type, only one capture stage S2 is present, given that the filter 1 lacks ionization electrodes, since the particular nature of the plate-like electrodes of the capture stage allows an efficient operation even without requiring an ionization stage and without the need for a final ozone removal stage. In addition, advantageously as specified hereinbelow, the provided power supply means of the plate-like electrodes of the capture stage allow maximizing the voltage on the same electrodes of such stage, also with the variation of the dielectric rigidity of the air.

[0055] As indicated hereinbelow, in the embodiment of electrostatic filter of two-stage type, also an ionization stage is present upstream of the capture stage. In this case, the power supply means voltage-drive the electrodes of such ionization stage in order to maintain a constant ionization current optimized for charging the particulate present in the air, without production of ozone or with a reduced production and within the limits of current law. In this case, the capture stage functions in the same way that the single-stage electrostatic filter functions, but the presence upstream of the ionization stage allows reducing the size and bulk of the plate-like electrodes of the capture stage.

[0056] Finally, as indicated hereinbelow, in the filter embodiment of three-stage type, the operation is analogous to that of the filter of two-stage type, with the further presence of a final stage of ozone removal placed downstream of the capture stage, which causes extremely small load losses upon the passage of the air and a complete removal of the ozone.

[0057] The electrostatic filter 1 is generally adapted to operate for purifying gaseous fluids of industrial processes and for purifying air in particular of airflow networks for civil use.

[0058] More in detail, the electrostatic filter 1, object of the present invention, comprises, in *a per se* known manner, at least one capture stage S2, which is placed to intercept the gas flow F that proceeds in an advancement direction, and is provided with at least one plate-like repulsion electrode 5 and with at least one plate-like collection electrode 6.

[0059] Such electrodes 5, 6 are arranged parallel to each other and in a manner substantially parallel to the advancement direction of the gas flow F.

[0060] Advantageously, the plate-like repulsion electrodes 5 and the plate-like collection electrodes 6 have plate form, in particular each being provided with two corresponding flat faces.

[0061] The plate-like repulsion electrodes 5 delimit, with the plate-like collection electrodes 6 adjacent thereto, passage channels which are extended along an extension direction thereof with constant thickness. Through such passage channels, the gas flow F is susceptible of passing, with its advancement direction parallel to the extension direction of the passage channels themselves.

[0062] In particular, the thickness of each passage channel is defined by the distance between the face of the corresponding plate-like repulsion electrode 5 and the face of the plate-like collection electrode 6 arranged facing the aforesaid face of the plate-like repulsion electrode 5 itself.

[0063] The electrostatic filter 1 then has power supply means adapted to supply such electrodes 5, 6 with a DC direct voltage potential difference, charging the plate-like repulsion electrode 5 to a positive potential V2 with respect to the plate-like collection electrode 6, preferably placed at ground potential, naturally determining the formation of an electric field between the aforesaid two electrodes.

[0064] According to the idea underlying the present invention, each plate-like repulsion electrode 5 is provided with a plurality of holes 12 preferably uniformly distributed in at least one area opposite the plate-like collection electrode 6.

[0065] The edges of connection of the aforesaid holes 12 with the two faces of the repulsion plate 5, have radii of curvature with localized concentrations of the electric field with consequent emission of positive electric charges 4 in the gas flow F, which participate in the ionization of the particles suspended in the same gas flow F.

[0066] Otherwise, the plate-like collection electrodes 6 lack holes and are thus solid, with their surface substantially lacking interruption.

[0067] Then, the holes 12 of the plate-like repulsion electrode 5 are arranged facing corresponding solid areas of the collection electrode 6.

[0068] In operation, the plate-like repulsion electrode 5 repels, towards the plate-like collection electrode 6, the impurity particles present in the gas flow F and which were positively charged, at least partially also with the positive electric charges 4 emitted by the edges of the plurality of holes 12.

[0069] The edges of the holes 12 therefore act as optimal field concentrator, locally at points distributed on the surfaces of the plate-like repulsion electrodes 5, capable of locally emitting charges and supplying the process, above all the field charging of the particles suspended in the gas flow F.

[0070] In Table 1, reported hereinbelow, the results of a capture efficiency comparison are reported. Such comparison was conducted by only power supplying the plates 5 and 6 in the two different cases with perforated and solid repulsion plates 5, so as to evaluate the efficiency variation due only to the holes 12. The results, reported in Table 1, presented unexpected values.

Table 1

	voltage [kV]	efficiencies 0.3 μm	0.4 μm
perforated plate	4	0.7539	0.7252
	5.5	0.7949	0.7576
solid plate	4	0.6466	0.6259
	5.5	0.7395	0.7345

Capture efficiency obtained by only power supplying the plates in two prototypes, one with perforated plates and one with solid plates, at two voltage levels, one below the trigger voltage and one close to discharge

[0071] The perforated plates have a higher efficiency, up to 10% higher than the solid plates due to the shape of the edges of the holes 12.

[0072] The edges of the holes 12 create zones of localized and concentrated field in the aforesaid capture stage S2. This concentration of the electric field is not sufficient for producing ozone but is sufficient for creating a field charging greater than the case with the solid plates. In addition, these points of concentrated and localized field are numerous and distributed (preferably in a uniform or otherwise random manner) on the surface (over most of the surface) and in particular at the center of the repulsion plates 5. From the obtained results, it is inferred that the largest particles, also considering the statistical validity of the results, are those which are more greatly affected by the variation of the force due to the holes 12, as would be expected if the effect was actually due to the phenomenon of field charging in the capture stage S2.

[0073] The holes 12 of the aforesaid plurality of holes therefore have for such purpose the edges with sufficiently small curvature radius, so as to allow locally concentrating the electric field to a value sufficient for generating charges but insufficient for generating micro-discharges such to produce ozone.

[0074] Together, or alternatively, the holes 12 can have, at their edge on at least one of the two faces of the repulsion plate 5, a projecting lip orthogonal to the surface of the same repulsion plate 5 susceptible of further concentrating the electric field to a value capable of generating charges. Such lip will be easily obtained by means of punching the repulsion plates 5 and due to the action of deformation of the punch, which projectingly pushes the metal of the plate 5 orthogonal to its lying plane.

[0075] Preferably, the aforesaid holes 12 have circular form with diameter comprised between 1 and 10 mm and advantageously substantially around 3 mm.

[0076] In accordance with the preferred embodiment illustrated in the enclosed figures, the holes 12 of the plate-like repulsion electrode 5 have equilateral triangle arrangement.

[0077] The holes 12 of the plate-like repulsion electrode 5 define, in the latter, a solid over void ratio comprised between 2 and 5. Such solid over void ratio corresponds with a configuration of the edges of the holes 12 (obtained in the plate-like repulsion electrode 5) that involves electric field concentrations such to emit positive charges 4 in an amount such to charge the impurity particles suspended in the gas flow F.

[0078] In particular, the aforesaid solid over void ratio corresponds to a number (or a density) of holes 12 of the plate-like repulsion electrode 5 such that the edges of the holes 12 have overall length which causes field concentration sites distributed over a significant area of the plate-like repulsion electrode 5 itself.

[0079] Suitably, the holes 12 of the plate-like repulsion electrode 5 are organized in a plurality of rows, in particular with a dense distribution in the corresponding area of the plate-like repulsion electrode 5 itself.

[0080] The positive potential V2, to which the plate-like repulsion electrodes 5 are charged, is in any case less than the avalanche discharge trigger value in the gas flow F in order to prevent the formation of ozone, though it can still be sufficient for triggering crown effect phenomena. Functionally, the repulsion electrodes 5 ionize the air due to the holes 12, creating a flow of positive charges which are directed towards the grounded collection plates 6. Thus, in their path of travel, such particles collide with particles suspended in the air or with molecules constituting the air itself, electrically charging them so as to be able to apply thereon the Coulomb force due to the electric field.

[0081] The collection plates 6 are metal plates placed at zero potential so as to generate an electrostatic field that attracts the impurities present in the air, once they have been positively charged due to the flow of charges also exiting from the repulsion electrodes 5; such impurities, which are accumulated on the collection plates 6, must therefore be periodically removed so as to maintain the filter 1 performance and hygiene levels.

[0082] Advantageously, the electrostatic filter 1, object of the present invention, also comprises at least one ionization stage S1, which is placed to intercept the gas flow F, upstream of the aforesaid capture stage S2, and is provided with at least one ionization electrode 2 and with at least one opposite field concentration electrode 3.

[0083] Such electrodes 2, 3 are power-supplied with a DC direct voltage potential difference with the ionization electrode 2 to a positive potential V1, and the field concentration electrode 3 to a lower potential, preferably at ground potential.

[0084] Preferably even if not necessarily, the ionization electrode 2 is at a positive potential V1 greater than the potential V2 of the plate-like repulsion electrode 5.

[0085] The function of the ionization electrodes 2, as the name suggests, is that of ionizing the air in a layer of thin thickness close to the electrode. Such ionization, known as crown effect, creates a flow of charges of the same sign of the electrode potential which are directed towards the grounded collection plates 6 such that, if in their path of travel they collide with particles suspended in the air or with molecules constituting the air itself, these are electrically charged and the Coulomb force due to the electric field can be applied thereon.

[0086] Analogous to the case of the filter of single-stage type, also in the case of two-stage filter, the collection plates 6 are solid metal plates placed at zero potential, so as to generate an electrostatic field that attracts the impurities present in the air once they have been charged due to the flow of charges also exiting from the ionization electrode 2; such impurities that are accumulated on the collection plates 6 must therefore be periodically removed, so as to maintain the filter 1 performance and hygiene levels. For example, aluminum collection plates with 0.5 mm thickness can be employed. The electrical continuity between the collection plates 6 can be ensured by rods 7 which also act as support in order to provide strength to the structure, as better specified hereinbelow. Such embodiment is in any case subjected to variations, which all have the same object of maintaining an electrical continuity between all the repulsion plates 5, different from that for the collection plates 6 which are also maintained at an identical ground potential, or with potential of opposite sign with respect to the repulsion potential.

[0087] In accordance with both the single-stage and two-stage embodiments, the positively-charged, metal perforated repulsion plates 5 are interposed between two collection plates 6, preferably at ground potential, and have the function of repelling the positively-charged particles towards the collection plates 6, facilitating the capture thereof: the same potential in fact allows obtaining a field with the same direction as the field created by the ionization electrode 2.

[0088] In other words, the potential V2 of the repulsion plate 5 has the same positive polarity as the potential of the ionization electrode 2 in order to repel, towards collection plate 6, the impurity particles charged both with the charges 4 emitted by the ionization electrode 2 and with the charges 4 emitted by the edges of the holes 12 of the repulsion plate 5. Advantageously, in accordance with the embodiment illustrated in the enclosed figures the ionization electrode 2 comprises at least one wire made of conductive material, arranged transverse to the air flow F opposite the field concentration electrode 3 formed by at least one metal plate parallel to the repulsion plate 5 and to the collection plate 6.

[0089] The plates of the field concentration electrodes 3, repulsion plate 5 and capture plate 6 are all obtained (both in the embodiment of single-stage type and in that of multiple-stage type) with metal blades, preferably made of aluminum, with thickness of about 0.5 mm, equidistant from each other and which are sequentially repeated in order to suitably treat an air flow F.

[0090] In accordance with one possible embodiment illustrated in the enclosed figures, the plates of the same type are electrically connected together by means of rods 7, 7', which simultaneously act as support and as spacers, and which traverse the plates of different type due to holes 8 provided therein in order to be mechanically connected to the ends of the support structure 20 of the electrostatic filter 1.

[0091] Preferably, end plates 60 are provided at ground potential, in order to keep the plates assembled together, and tie rods 61 are provided that are connected to the support structure 20 in order to compact the plate assembly.

[0092] Since the electrodes of the collection plate 6 and of the field concentration plate 3 are both at ground potential, these can be obtained with two contiguous areas of a single metal blade, as shown in figure 3A (in which the holes 12 were not illustrated in detail, since this is a schematic drawing).

[0093] The filiform ionization electrodes 2 may be provided, mainly due to production costs, only for each group of multiple plates, repulsion 5 and capture 6 plates, since they are able to generate charges susceptible of traversing the multiplicity of chambers defined between the aforesaid pairs of repulsion 5 and capture 6 plates.

[0094] The ionization electrodes 2 will be advantageously obtained with tungsten wires with diameter equal to 0.1 mm - 0.5 mm.

[0095] In figures 4 and 5, the ionization electrodes 2 of filiform type are visible. The latter are mechanically connected to the support structure 20 through coupling means advantageously comprising a pair of transverse rods 9, supporting the terminals 10 of the wires 2 that are arranged taut through the springs 11.

[0096] In the case of the embodiment of the electrostatic filter 1 with two stages, power supply means are advantageously provided comprising two separate power supplies, in order to power supply the ionization electrodes 2 at the positive operating potential V1 with respect to the field concentration electrodes 3 placed at the ground potential and in order to power supply the repulsion plates 5 at the positive operating potential V2 with respect to the collection plates 6 also placed at the ground potential.

[0097] For such purpose, the power supply means thus comprise a first power supply 13, which is current-driven in order to power supply the ionization electrode 2 at the aforesaid operating potential V1, which will be varied in order to maintain the ionization current I1 at a value lower than a preset Imax, capable of preventing an excessive formation of ozone, and advantageously comprised between two preset values Imin and Imax.

[0098] In addition, the power supply means also comprise at least one second power supply 14, which is voltage-driven in order to power supply the repulsion plate 5 at an operating potential V2 which will be varied so as to maintain the maximum possible potential without triggering discharges between the plates 5 and 6 of the capture stage S2.

[0099] In the ionization stage S1, the potential V1 is selected for example with value higher than the crown effect trigger voltage for a considerable production of charges 4 in the gas flow F, but with value lower than the avalanche effect trigger potential which would lead to a consequent high production of ozone.

[0100] With the increase of the voltage, the electric field increases and the ionization current in the air increases due to the emitted charges. It has been experimentally established that there is a threshold voltage due to the specific configuration of the geometry of the plates and the environmental conditions, which thus corresponds to a threshold electric field, at which there is an important and discontinuous increase of the ionization current susceptible of producing ozone. Consequently, it has been selected to optimize the maximum voltage value for the specific configuration of electrodes 2, 3, by controlling the current I1 at the specific changeable environmental conditions such that it does not exceed a threshold value Ilmax, corresponding to a non-linearity in the increase of current for triggering micro-discharge phenomena.

[0101] More in detail, the first power supply 13 applies a potential V1 to the ionization electrodes 2, as seen preferably filiform and made of conductive material, capable of bringing field concentrations (dependent on the specific configuration of electrodes and on the specific environmental conditions) susceptible of triggering the crown effect, without pushing this potential to levels corresponding to a production of ozone, or an excessive production of ozone. At such potential and electric field value (which as stated still depends on the configuration of the electrodes and on the environmental conditions), a weak electric current is generated in the gas flow F which traverses the electrostatic filter, such current made possible by the ions generated by the same crown effect. This current is itself a source of ion generation in the air, and hereinbelow is termed with the expression ionization current I1. Correspondingly, the electrode 2 is the stressed electrode or ionization electrode.

[0102] The potential V1 must be regulated in order to allow attaining the ionization current I1 and maintaining it stable below a value that does not produce ozone, or which does not cause the avalanche discharge effect. By keeping this ionization current I1 stable, it is possible to maximize the filtration efficiency, even with the variation of the dielectric rigidity of the gas that transits in the filter, for example caused, in the case of air, by the variation of the humidity level, by the pressure, by the temperature and by the presence of gaseous ions. More clearly, in the ionization stage, the driving of the first power supply 13 is aimed to maintain the ionization current I1 at a specific level, and to stably keep it at this level, even if there is a change of the physical conditions (temperature, pressure, humidity, load of ions, etc.) of the gas that traverses the filter, and at a level where ozone is not produced. For example, in the case of air, if its humidity content drops, the ionization current I1 could decrease for a specific potential difference V1. The first power supply 13 will then automatically react, increasing the potential V1 in a manner so as to re-establish the current I1 to the preset level, while not exceeding a dangerous value for the production of ozone. This characteristic therefore allows maintaining the filtration efficiency constant, maintaining constant the generation of ions in the air to be filtered.

[0103] It has in fact been established that with an increased production of ozone by the first ionization stage S1, there is an increase of conductivity in the air and hence an increase of current I1 which is enclosed in the field concentration plate 3.

[0104] Therefore, once the characteristics of the environment and the type of air exchange present are known, it is possible to estimate (also experimentally) the production of ozone admitted (or better yet the admitted ozone generation rate) such to not exceed the limit allowed by law and guidelines and normally considered today equal to maximum 50 ppb (according to the most stringent norms) for all types of work, but which can, if desired, be fixed at a substantially lower limit so as to not exceed the ozone base naturally present in the air. After having estimated the maximum admissible current I1 such that the limit is not exceeded, the voltage generator 13 is current-driven, in a manner so as to not allow exceeding such maximum current Ilmax that passes in the air between the high-voltage ionization electrode 2 and the zero potential of the plate-like field concentration electrode 3.

[0105] In order to vary the current, it is necessary to modify the voltage on the ionization electrode 2, responsible for the ionization current. In the presence of multiple filters, in order to attain a relatively simple control, it can be assumed that the current measurement is the same in all the filters, and equal to that measured on a master filter taken as a sample. One possible control procedure is therefore the following:

1. supplying the ionization electrode 2 of the filter with voltages lower than the trigger voltage;
2. with voltage on the plates 3, 5, 6, increase the voltage V1 on the ionization electrode 2 until also the current I1 begins to increase;
3. once the maximum admissible current Ilmax point has been reached, block the voltage at such value, as a precaution at a slightly lower value;
4. at regular time intervals, control that the current value I1 remains below the maximum value Ilmax, otherwise proceed automatically with the reduction of the voltage V1 or, in case of lowering below the desired value, the procedure is repeated from point 2.

[0106] The described control and procedure can be obtained with a very low cost and with a very simple algorithm, such that it can also be obtained in an analogue manner. The possibility of considering, in the control algorithm, also other parameters such as the environmental state (temperature, pressure, humidity, etc.) and state of the air (concentration of ozone, CO2, etc.) in any case leads to the preference for the electronic-digital control, where sensors for the abovementioned quantities can be easily integrated.

[0107] In addition, a control on the current also allows monitoring other parameters necessary for the good operation of the filter and of the associated electronics such as:

- presence of discharges that can damage the control electronics. The discharge is in fact identified by a sudden current increase: monitoring the current, e.g. above a certain threshold, signifies knowing when and how many discharges have been verified. In the presence of the discharge, it is possible to reduce the electrode voltage and bring the current to lower values where the discharge does not occur;
- filter dirt level. If the voltage necessary for preventing discharges is clearly lower than the nominal condition, this signifies that there is a path between the plates that facilitates the passage of current, due to a foreign body that entered into the filter or dirt accumulated on the plates, which reduces the insulating air space between the plates.
- breakage of the ionization electrodes 2. During the operation of the filter, the electrodes are consumed by varying the ionization conditions. Corrosion leads the electrode 2 to break, causing a sudden and permanent variation that can be measured in the current.

[0108] The second power supply 14 of the power supply means is employed in the capture stage S2 and is adapted to maintain the voltage V2 on the plate-like repulsion electrodes 5 at the maximum possible potential, without triggering electrical discharges between repulsion 5 and capture 6 plates, thus optimizing the capture efficiency. The driving of the operating voltage V2 for this second power supply 14 is based on the detection of the voltage between the plate-like repulsion electrodes 5 and the grounded capture electrodes 6, maintaining it below a presettable maximum potential V2max.

[0109] The potential V2 is for such purpose modulated so as to be fixed each time on the maximum possible voltage, without causing electrical discharges between repulsion plates 5 and grounded collection plates 6. The attainment of the maximum possible voltage, as a function of a specific dielectric rigidity of the air, which is subjected to variations during the day according to the current environmental conditions, allows maintaining the filter efficiency always at the maximum, with regard to the removal of particulate from the air.

[0110] The second power supply 14 regulates the voltage V2 by means of feedback on the stability of the current 12, i.e. over the time progression thereof; as soon as micro-discharges are detected with unstable progression with little current peaks, the voltage V2 on the repulsion plates 5 is lowered.

[0111] The voltage V2 is then automatically regulated through a control board that sets the current 12 at a level just lower than that susceptible of generating the maximum V2, at which the discharges occur.

[0112] At the voltage V2 provided for the repulsion plates lower than the voltage of the ionization electrodes 2, and advantageously for example at about half the supply voltage V1 of the ionization electrode 2, the holes 12 of the perforated repulsion plates 5 do not cause any increase of ozone. By power supplying such plates 5 for example up to 5 kV (an exemplifying value that accounts for a distance between the collection plates of less than 6mm), it has been established that the ozone concentration remains fixed at the environmental value. Advantageously, for example, in order to prevent the capture stage S2 from introducing ozone into the air flow F, the repulsion plate 5 is power-supplied at an operating potential V2 less than 6KV (and preferably less than 5.5 KV) with distance between the repulsion plates 5 and the collection plates 6 of less than 5 mm.

[0113] The operating potential V2 of said repulsion plate 5 will also be substantially preferably in the order of magnitude of half the operating potential V1 applied to the ionization electrode 2. The synergy between two modulation mechanisms, on V1 and V2, allows maintaining the efficiency of the filter 1 at maximum levels, in any environmental conditions.

[0114] According to a further advantageous but optional characteristic of the present invention, the electrostatic filter 1 also comprises a third stage for removing the ozone S3 provided with reducing means 40 constituted by plates substantially parallel to the advancement direction of said gas flow (F) and placed to intercept the air flow F downstream of the capture stage S2 in order to reduce the ozone present in the air flow F.

[0115] Ozone is a very reactive and highly oxidizing gas, reason for which it is dangerous; by placing it in contact with a good reducing agent, it reacts and disappears from the gases that exit from the filter. Among the reducing agents, coal has been advantageously selected, in the form of graphite plates with which it is possible to construct a third stage, connected in cascade to the second stage. In such a manner, the ozone possibly produced in the first stage and possibly in extremely small (or zero) quantities by the holes of the second stage, would pass, after having been recombined to minimum extend, into the third stage where the presence of the coal-based reducing agent would transform it into CO_2.

[0116] Advantageously, a very low electric potential may be applied on the coal plates, which in such a manner are able to change the outcome of the reaction with the ozone from carbon dioxide to oxygen. The relatively low concentration of ozone to be removed would ensure the operation of the third stage for various months before being substituted, thus allowing the optimization of the ordinary maintenance interventions.

[0117] As mentioned above, the electrostatic filter 1 can be constituted in accordance with a first embodiment of the invention, by a single capture stage S2, with perforated repulsion plates 5 and with a single power supply which will drive the positive voltage V2 on the same perforated plates. Said plates 5 for this particular single-stage embodiment will have to have size greater than that of a multi-stage filter, in order to compensate for the absence of the ionization stage in the production of positive charges.

[0118] Otherwise, the electrostatic filter 1 can be constituted in accordance with a second embodiment of the invention, by two stages including an ionization S1 and a capture S2 stage, both power-supplied by separate power supplies controlled in a different manner as expressed above, in order to minimize the production of ozone in the ionization stage and maximize the repulsion force on the charged particles in the capture stage.

[0119] Finally, the electrostatic filter 1 can comprise, in accordance with a third embodiment, also a third stage for removing the ozone, advantageously placed downstream of the capture stage, mainly in the case of the simultaneous presence of an ionization stage upstream, but, in the more general case, simply provided downstream of the capture stage even if the latter is not preceded by the ionization stage.

[0120] Of course, the electrostatic filter 1, in the practical achievement thereof, can also assume shapes and configurations that are different from that illustrated above, without departing from the present protective scope, which is defined by the appended claims.

[0121] In addition, all details can be substituted by technically equivalent elements and the size, shapes and materials used can be of any type according to the requirements.

Claims

1. Electrostatic filter (1) for purifying a gas flow, such electrostatic filter comprising:

   - at least one capture stage (S2) provided with at least one plate-like repulsion electrode (5) and with at least one plate-like collection electrode (6), parallel to each other and arranged for intercepting a gas flow (F) susceptible of proceeding in an advancement direction parallel to said electrodes (5, 6);

- power supply means adapted to charge said plate-like repulsion electrode (5) to a positive potential (V2) with respect to said plate-like collection electrode (6), determining an electric field between said electrodes (5, 6);

wherein said plate-like repulsion electrode (5) is provided with a plurality of holes (12) distributed on its surface, whose edges of connection with its two faces have radii of curvature with localized concentrations of said electric field, with consequent emission of positive electric charges (4) in said gas flow (F);
said plate-like repulsion electrode (5) being arranged for repelling impurity particles in suspension in said gas flow (F) and positively charged with said positive electric charges (4) emitted by the edges of said plurality of holes (12) towards said plate-like collection electrode (6);
characterized in that said plate-like repulsion electrode (5) has a solid over void ratio, due to the plurality of said holes (12), comprised between 2 and 5;
wherein said plate-like repulsion electrodes (5) and said plate-like collection electrodes (6) have flat form;
said plate-like repulsion electrodes (5) delimiting, with said plate-like collection electrodes (6), passage channels which are extended along an extension direction thereof with constant thickness, and through such passage channels said gas flow (F) is susceptible of passing with said advancement direction parallel to said extension direction of said passage channels.

2. Electrostatic filter (1) according to claim 1, **characterized in that** the holes (12) of said plurality of holes (12) are of circular form with diameter comprised between 1 and 10 mm.

3. Electrostatic filter (1) according to claim 2, **characterized in that** the holes (12) of said plurality of holes (12) have 3 mm diameter.

4. Electrostatic filter (1) according to claim 1, **characterized in that** the holes (12) of said plurality of holes (12) have equilateral triangle arrangement.

5. Electrostatic filter (1) according to claim 1, **characterized in that** it comprises at least one ionization stage (S1) arranged to intercept, upstream of said capture stage (S2), said gas flow (F) and provided with at least one ionization electrode (2) and with an opposite field concentration electrode (3); said power supply means being adapted to charge said ionization electrode (2) to a positive potential (V1) with respect to said plate-like collection electrode (6).

6. Electrostatic filter (1) according to claim 1, **characterized in that** the holes (12) of said plurality of holes (12), have a projecting lip at said edge, said lip being arranged orthogonal to the surface of said plate-like repulsion electrode (5), and provided with at least one curvature with electric field concentrations for generating positive charges (4) in said gas flow (F).

7. Electrostatic filter (1) according to claim 5, **characterized in that** said power supply means comprise:

- at least one first power supply (13) arranged for adjusting an ionization current (II) that flows between said ionization electrode (2) and said opposite field concentration electrode (3) to a value lower than a preset maximum value (Imax);
- and at least one second power supply (14) arranged for adjusting the voltage between said plate-like repulsion electrode (5) and said plate-like collection electrode (6) by means of feedback on the time progression of a current (12) that flows between them.

8. Electrostatic filter (1) according to any one of the preceding claims, **characterized in that** it comprises reducing means (40) comprising multiple plates and arranged for intercepting, downstream of said capture stage (S2), said gas flow (F) having said advancement direction parallel to the plates of said reducing means (40), in order to reduce the ozone present in said gas flow (F).

9. Electrostatic filter (1) according to claim 8, **characterized in that** said reducing means (40) comprise at least one voltage-supplied graphite plate.

10. Electrostatic filter (1) according to any one of the preceding claims, **characterized in that** each said plate-like collection electrode (6) is placed at ground potential.

11. Electrostatic filter (1) according to any one of the preceding claims, **characterized in that** said holes (12) are uniformly distributed in at least one area opposite said plate-like collection electrode (6).

Patentansprüche

1. Elektrostatischer Filter (1) zur Reinigung eines Gasstroms, wobei dieser elektrostatische Filter Folgendes umfasst:

   - mindestens eine Abscheidungsstufe (S2), die mit mindestens einer plattenförmigen Repulsionselektrode (5) und mit mindestens einer plattenförmigen Sammelelektrode (6) ausgestattet ist, die parallel zueinander und zum Abfangen eines Gasstroms (F) vorgesehen sind, der geeignet ist, in einer Vorwärtsrichtung parallel zu den genannten Elektroden (5, 6) zu strömen;
   - Stromversorgungsmittel, die zum Laden der genannten plattenförmigen Repulsionselektrode (5) auf ein positives Potential (V2) im Vergleich zu der genannten plattenförmigen Sammelelektrode (6) vorgesehen sind, wodurch ein elektrisches Feld zwischen den genannten Elektroden (5, 6) entsteht;

   bei dem die genannte plattenförmige Repulsionselektrode (5) mit einer Vielzahl von auf deren Oberfläche verteilten Öffnungen (12) ausgestattet ist, deren Verbindungsränder mit ihren beiden Flächen Biegeradien mit lokalisierten Konzentrationen des genannten elektrischen Feldes aufweisen, mit daraus folgender Emission von positiven elektrischen Ladungen (4) in den genannten Gasstrom (F); wobei die genannte plattenförmige Repulsionselektrode (5) zur Abstoßung von in dem genannten Gasstrom (F) suspendierten, mit den genannten positiven elektrischen Ladungen (4) positiv geladenen Verschmutzungspartikeln angeordnet ist, die von den Rändern der genannten Vielzahl von Öffnungen (12) in Richtung der genannten plattenförmigen Sammelelektrode (6) emittiert werden;
   dadurch gekennzeichnet, dass die genannte plattenförmige Repulsionselektrode (5) ein Feststoff-/Hohlraumverhältnis aufgrund der Vielzahl der genannten Öffnungen (12) zwischen 2 und 5 aufweist;
   bei dem die genannte plattenförmige Repulsionselektrode (5) und die genannte plattenförmige Sammelelektrode (6) eine flache Form aufweisen;
   wobei die genannten plattenförmigen Repulsionselektroden (5) mit den genannten plattenförmigen Sammelelektroden (6) Durchgangskanäle begrenzen, die entlang einer Verlaufsrichtung derselben mit konstanter Stärke verlaufen, und durch die genannten Durchgangskanäle der genannte Gasstrom (F) geeignet ist, in der genannten Vorwärtsrichtung parallel zu der genannten Verlaufsrichtung der genannten Durchgangskanäle zu strömen.

2. Elektrostatischer Filter (1) nach Anspruch 1, **dadurch gekennzeichnet, dass** die Öffnungen (12) der genannten Vielzahl von Öffnungen (12) kreisförmig sind mit einem Durchmesser zwischen 1 und 10 mm.

3. Elektrostatischer Filter (1) nach Anspruch 2, **dadurch gekennzeichnet, dass** die Öffnungen (12) der genannten Vielzahl von Öffnungen (12) einen Durchmesser von 3 mm aufweisen.

4. Elektrostatischer Filter (1) nach Anspruch 1, **dadurch gekennzeichnet, dass** die Öffnungen (12) der genannten Vielzahl von Öffnungen (12) als ein gleichseitiges Dreieck angeordnet sind.

5. Elektrostatischer Filter (1) nach Anspruch 1, **dadurch gekennzeichnet, dass** er mindestens eine Ionisationsstufe (S1) umfasst, die zum Abfangen vor der genannten Abscheidungsstufe (S2) des genannten Gasstroms (F) angeordnet und mit mindestens einer Ionisationselektrode (2) und mit einer Gegenfeld-Konzentrationselektrode (3) ausgestattet ist; wobei die genannten Stromversorgungsmittel zum Laden der genannten Ionisationselektrode (2) auf ein positives Potential (V1) im Vergleich zu der genannten plattenförmigen Sammelelektrode (6) geeignet sind.

6. Elektrostatischer Filter (1) nach Anspruch 1, **dadurch gekennzeichnet, dass** die Öffnungen (12) der genannten Vielzahl von Öffnungen (12) eine vorstehende Lippe an dem genannten Rand aufweisen, wobei die genannte Lippe orthogonal zur Oberfläche der genannten plattenförmigen Repulsionselektrode (5) angeordnet und mit mindestens einer Krümmung mit Konzentrationen des elektrischen Feldes zur Erzeugung von positiven Ladungen (4) in dem genannten Gasstrom (F) ausgestattet ist.

7. Elektrostatischer Filter (1) nach Anspruch 5, **dadurch gekennzeichnet, dass** die genannten Stromversorgungsmittel Folgendes umfassen:

   - mindestens eine erste Stromversorgung (13) zur Einstellung eines Ionisationsstroms (I1), der zwischen der genannten Ionisationselektrode (2) und der genannten Gegenfeld-Konzentrationselektrode (3) strömt, auf einen geringeren Wert als einen voreingestellten Höchstwert (Imax);
   - und mindestens eine zweite Stromversorgung (14) zur Einstellung der Spannung zwischen der genannten plattenförmigen Repulsionselektrode (5) und der genannten plattenförmigen Sammelelektrode (6) durch Rückmeldung hinsichtlich des Zeitverlaufs eines dazwischen strömenden Stroms (I2).

8. Elektrostatischer Filter (1) nach einem beliebigen der vorangegangenen Ansprüche, **dadurch gekennzeichnet, dass** er Reduktionsmittel (40) umfasst, die mehrere Platten umfassen und zum Abfangen nach der genannten Abscheidungsstufe (S2) des genannten Gasstroms (F) mit der genannten Vorwärtsrichtung parallel zu den Platten der genannten Reduktionsmittel (40) angeordnet sind, um das in dem genannten Gasstrom (F) enthaltene Ozon zu reduzieren.

9. Elektrostatischer Filter (1) nach Anspruch 8, **dadurch gekennzeichnet, dass** die genannten Reduktionsmittel (40) mindestens eine spannungsversorgte Graphitplatte umfassen.

10. Elektrostatischer Filter (1) nach einem beliebigen der vorangegangenen Ansprüche, **dadurch gekennzeichnet, dass** jede plattenförmige Sammelelektrode (6) auf Erdpotential platziert ist.

11. Elektrostatischer Filter (1) nach einem beliebigen der vorangegangenen Ansprüche, **dadurch gekennzeichnet, dass** die genannten Öffnungen (12) in mindestens einem der genannten plattenförmigen Sammelelektrode (6) gegenüberliegenden Bereich gleichmäßig verteilt sind.

Revendications

1. Filtre électrostatique (1) pour purifier un flux de gaz, ce filtre électrostatique comprenant :

   - au moins un étage de capture (S2) pourvu d'au moins une électrode de répulsion en forme de plaque (5) et d'au moins une électrode de collecte en forme de plaque (6), parallèle l'une à l'autre et disposées pour intercepter un flux de gaz (F) susceptible de procéder dans une direction d'avancement parallèle auxdites électrodes (5, 6) ;
   - des moyens d'alimentation électrique pour charger ladite électrode de répulsion en forme de plaque (5) à un potentiel positif (V2) par rapport à ladite électrode de collecte en forme de plaque (6), déterminant un champ électrique entre lesdites électrodes (5, 6) ;

   où ladite électrode de répulsion en forme de plaque (5) est pourvue d'une pluralité de trous (12) distribués sur sa surface, dont les bords de connexion avec ses deux faces ont des rayons de courbure avec des concentrations localisées dudit champ électrique, avec une émission conséquente des charges électriques positives (4) dans ledit flux de gaz (F) ;
   ladite électrode de répulsion en forme de plaque (5) étant disposée pour repousser des particules d'impureté en suspension dans ledit flux de gaz (F) et chargée positivement avec lesdites charges électriques positives (4) émises par les bords de ladite pluralité de trous (12) vers ladite électrode de collecte en forme de plaque (6) ;
   caractérisé en ce que ladite électrode de répulsion en forme de plaque (5) a un rapport solide sur vide, dû à la pluralité desdits trous (12), compris entre 2 et 5 ;
   où lesdites électrodes de répulsion en forme de plaque (5) et lesdites électrodes de collecte en forme de plaque (6) ont une forme plate ;
   lesdites électrodes de répulsion en forme de plaque (5) délimitant, avec lesdites électrodes de collecte en forme de plaque (6), des canaux de passage qui sont étendus le long d'une direction d'extension de ceux-ci avec une épaisseur constante, et à travers ces canaux de passage ledit flux de gaz (F) est susceptible de passer avec ladite direction d'avancement parallèle à ladite direction d'extension desdits canaux de passage.

2. Filtre électrostatique (1) selon la revendication 1, **caractérisé en ce que** les trous (12) de ladite pluralité de trous (12) sont de forme circulaire avec un diamètre compris entre 1 et 10 mm.

3. Filtre électrostatique (1) selon la revendication 2, **caractérisé en ce que** les trous (12) de ladite pluralité de trous (12) ont un diamètre de 3 mm.

4. Filtre électrostatique (1) selon la revendication 1, **caractérisé en ce que** les trous (12) de ladite pluralité de trous (12) ont un agencement en triangle équilatéral.

5. Filtre électrostatique (1) selon la revendication 1, **caractérisé en ce qu'**il comprend au moins un étage d'ionisation (S1) disposé pour intercepter, en amont dudit étage de capture (S2), ledit flux de gaz (F) et pourvu d'au moins une électrode d'ionisation (2) et d'une électrode de concentration de champ opposé (3) ; lesdits moyens d'alimentation électrique étant adaptés pour charger ladite électrode d'ionisation (2) à un potentiel positif (V1) par rapport à ladite électrode de collecte en forme de plaque (6).

6. Filtre électrostatique (1) selon la revendication 1, **caractérisé en ce que** les trous (12) de ladite pluralité de trous (12) ont un rebord saillant au niveau dudit bord, ledit rebord étant disposé orthogonal à la surface de ladite électrode de répulsion en forme de plaque (5), et pourvu d'au moins une courbure avec des concentrations de champ électrique pour générer des charges positives (4) dans ledit flux de gaz (F).

7. Filtre électrostatique (1) selon la revendication 5, **caractérisé en ce que** lesdits moyens d'alimentation électrique comprennent :

   - au moins une première alimentation électrique (13) disposée pour régler un courant d'ionisation (I1) qui s'écoule entre ladite électrode d'ionisation (2) et ladite électrode de concentration de champ opposé (3) à une valeur inférieure à une valeur maximale prédéfinie (Imax) ;
   - et au moins une seconde alimentation électrique (14) disposée pour régler la tension entre ladite électrode de répulsion en forme de plaque (5) et ladite électrode de collecte en forme de plaque (6) au moyen d'une rétroaction sur la progression temporelle d'un courant (I2) qui s'écoule entre elles.

8. Filtre électrostatique (1) selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'**il comprend des moyens de réduction (40) comprenant des plaques multiples et disposés pour intercepter, en aval dudit étage de capture (S2), ledit flux de gaz (F) ayant ladite direction d'avancement parallèle aux plaques desdits moyens de réduction (40), de manière à réduire l'ozone présent dans ledit flux de gaz (F).

9. Filtre électrostatique (1) selon la revendication 8, **caractérisé en ce que** lesdits moyens de réduction (40) comprennent au moins une plaque de graphite alimentée en tension.

10. Filtre électrostatique (1) selon l'une quelconque des revendications précédentes, **caractérisé en ce que** chaque électrode de collecte en forme de plaque (6) est placée à un potentiel de terre.

11. Filtre électrostatique (1) selon l'une quelconque des revendications précédentes, **caractérisé en ce que** lesdits trous (12) sont distribués de manière uniforme dans au moins une zone opposée à ladite électrode de collecte en forme de plaque (6).

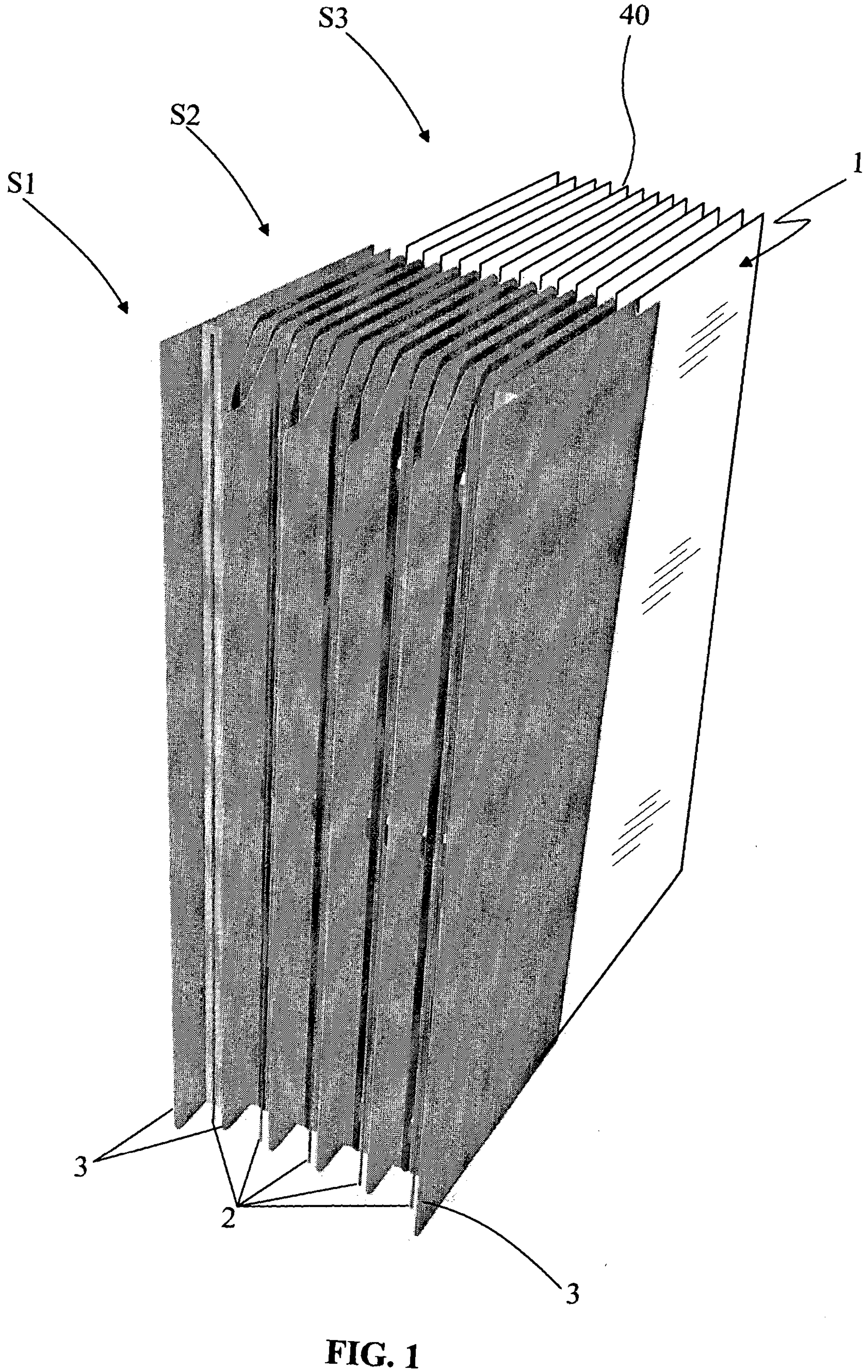

FIG. 1

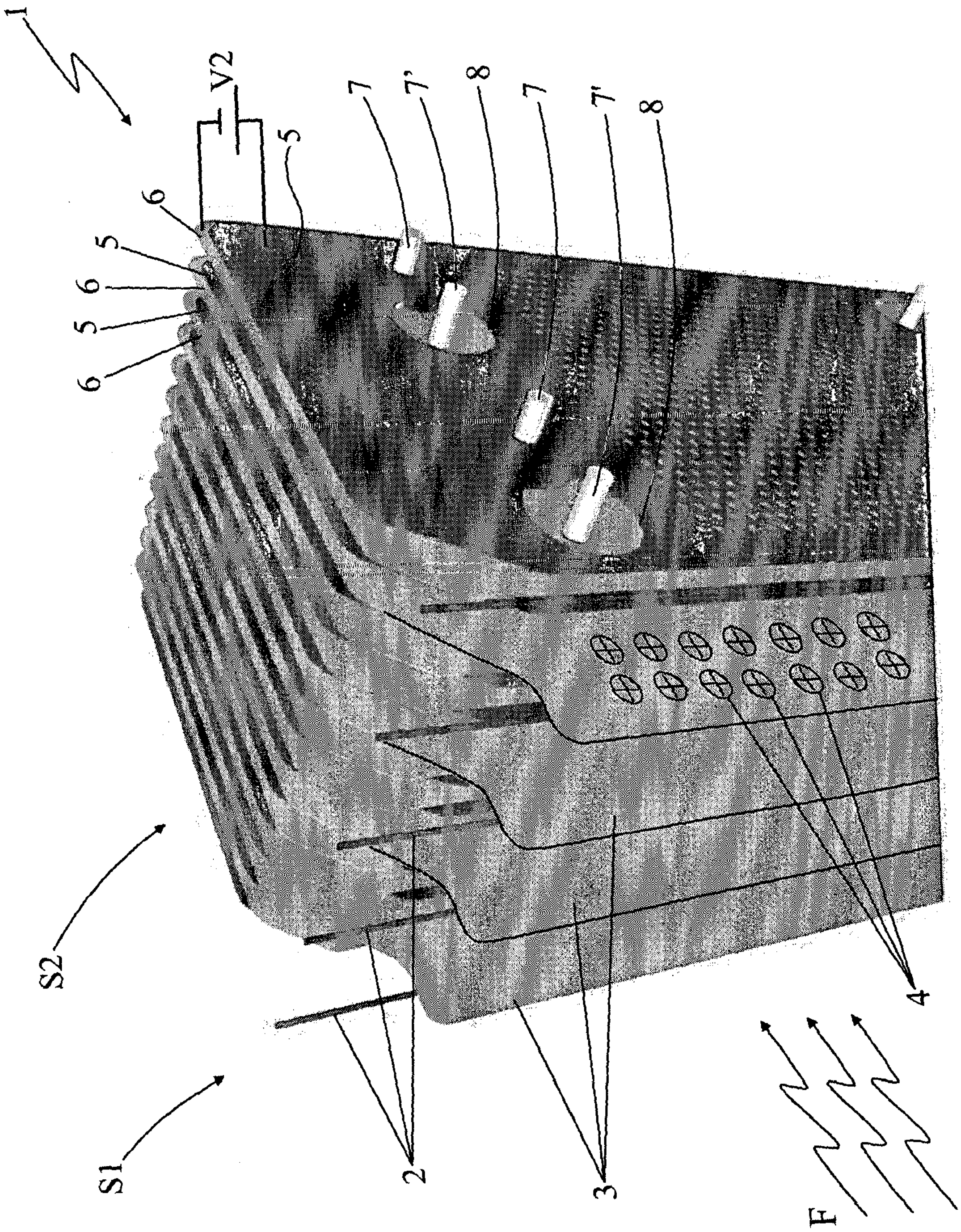

FIG. 2

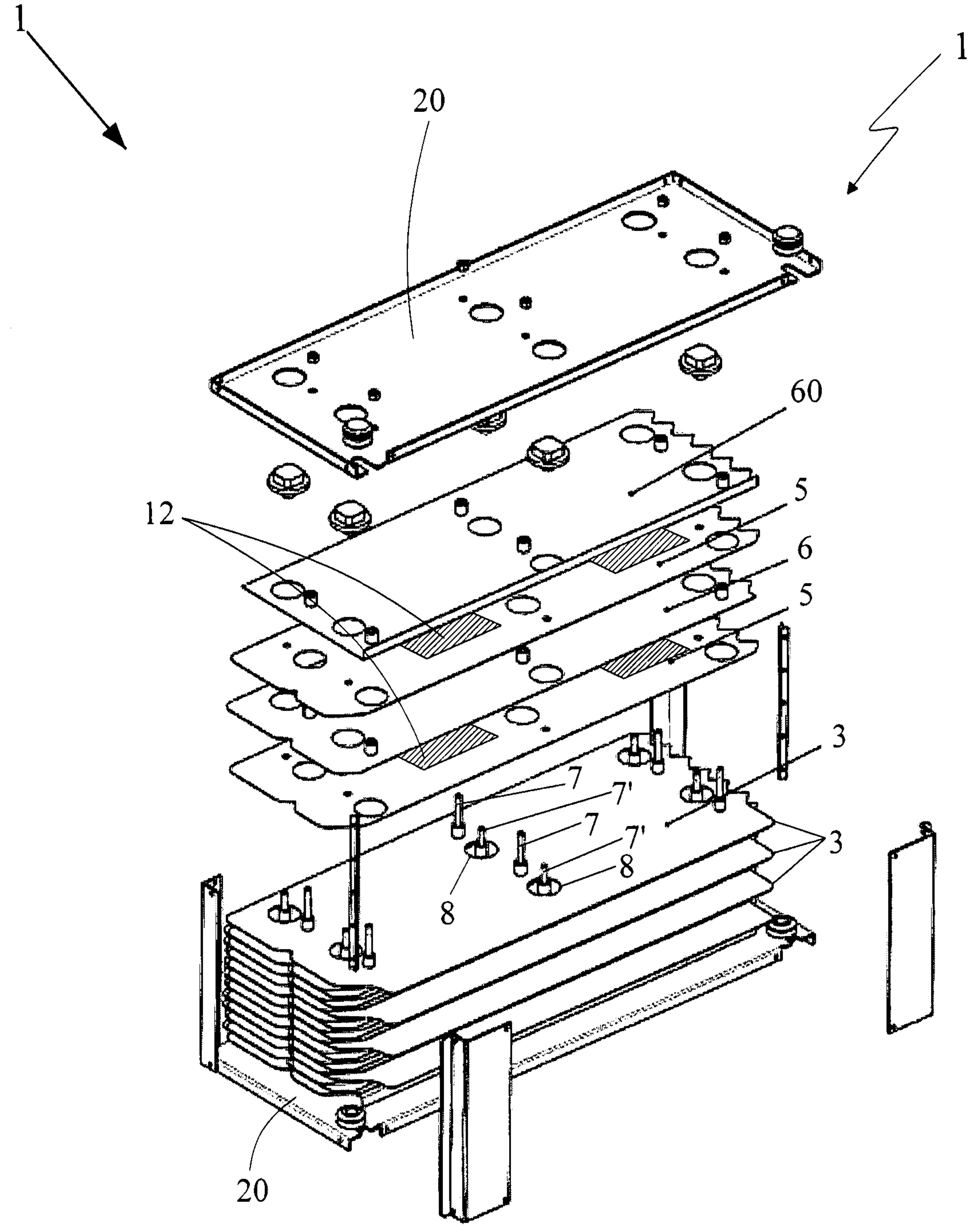

FIG. 3A

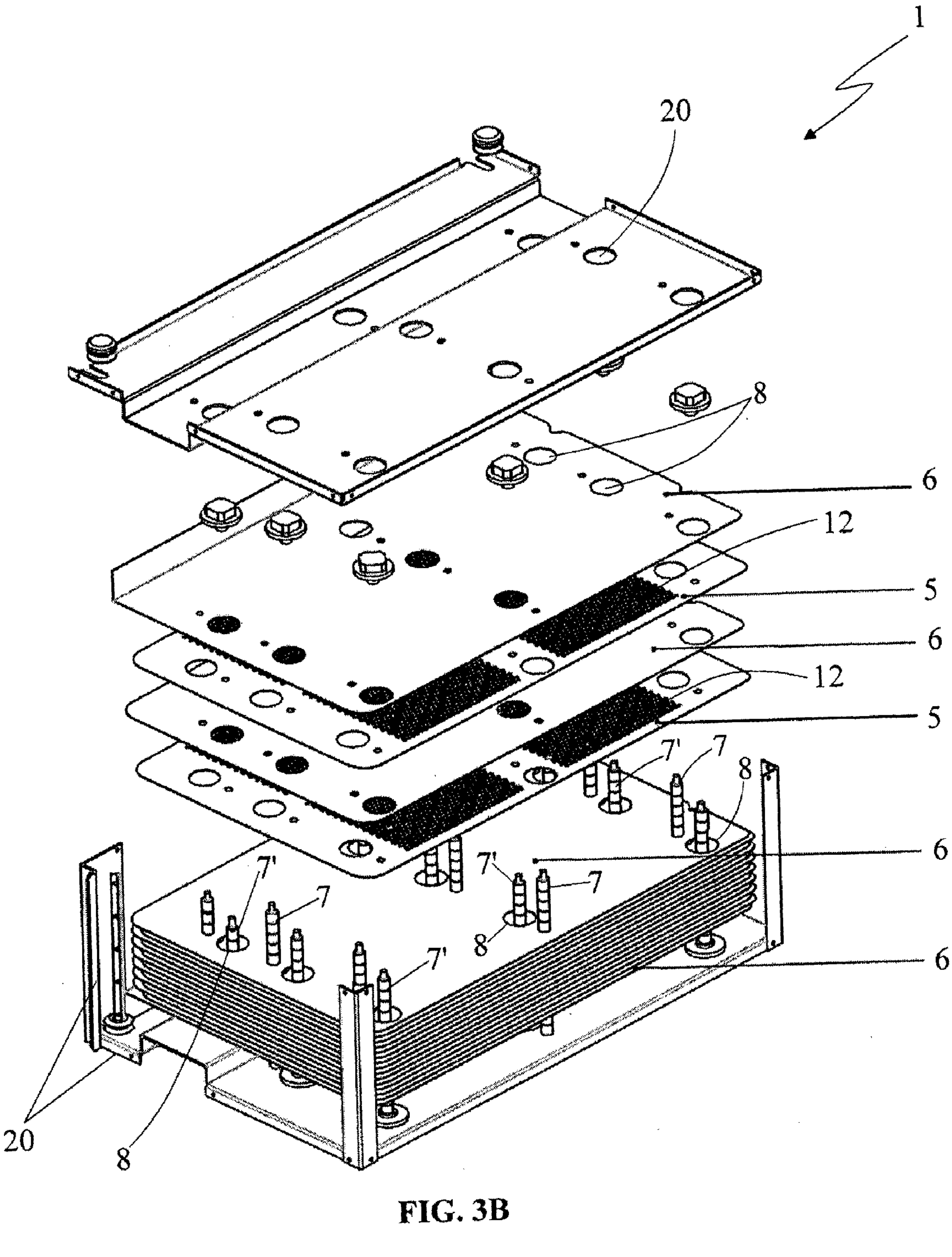

FIG. 3B

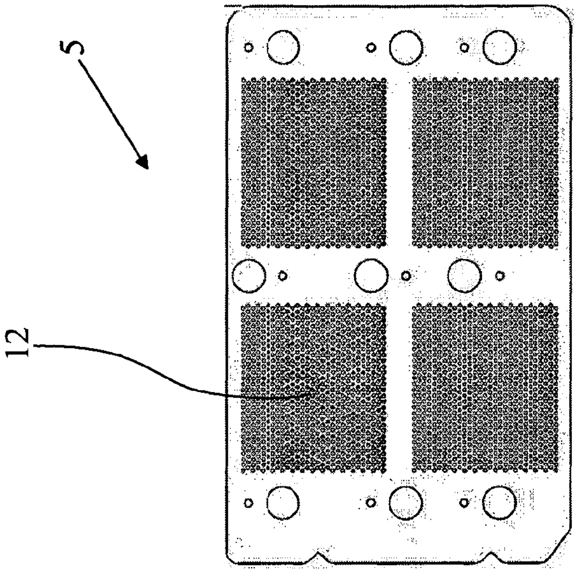

FIG. 6B

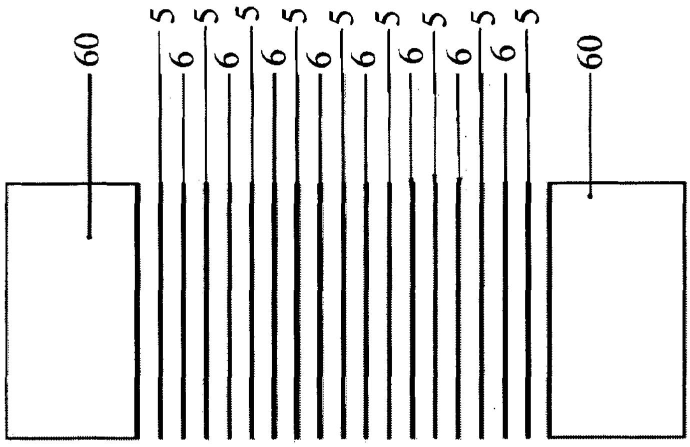

FIG. 3D

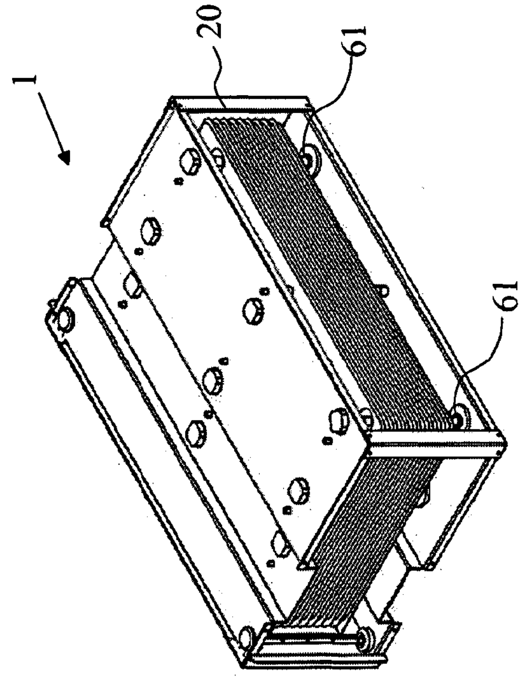

FIG. 3C

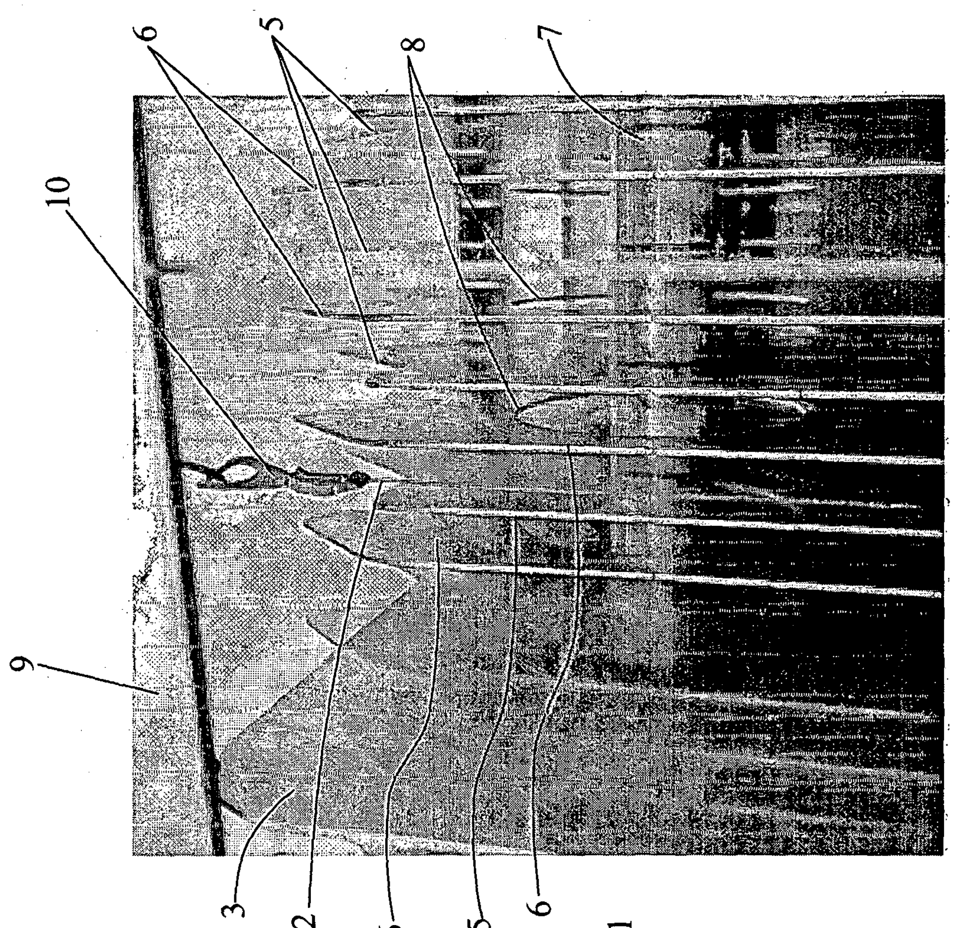

FIG. 5

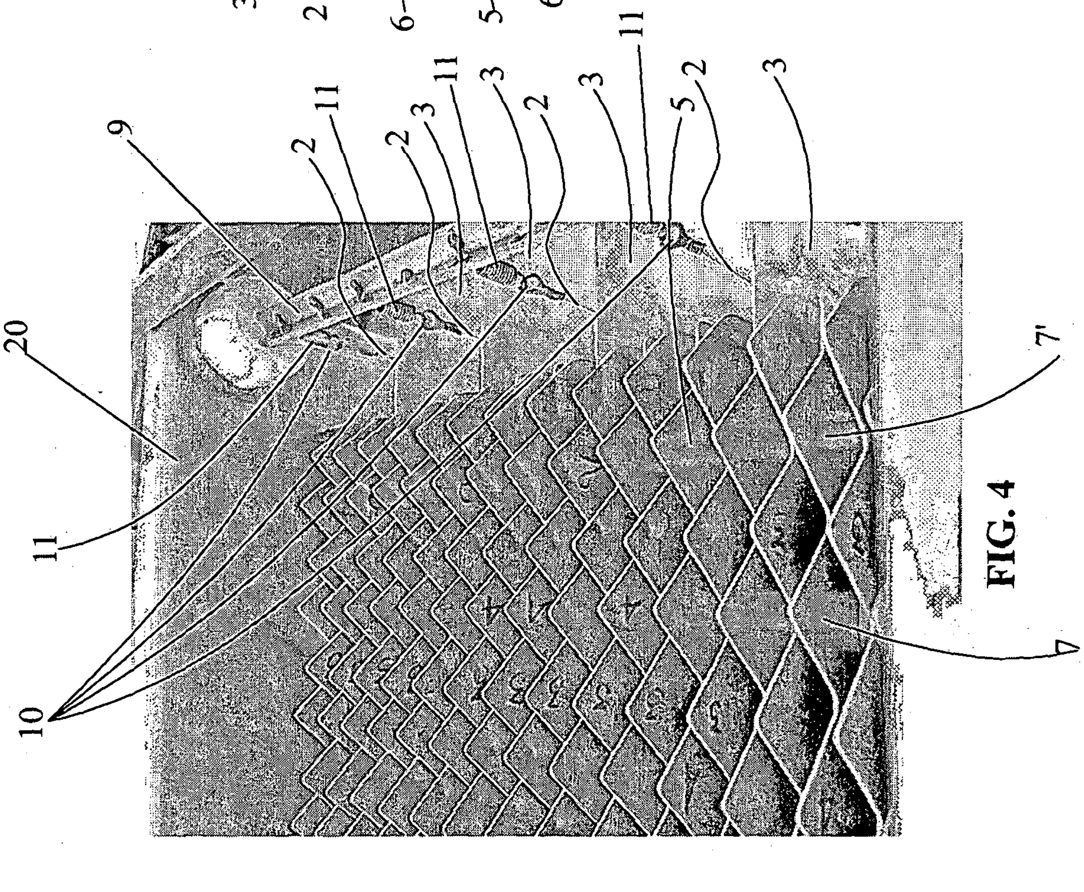

FIG. 4

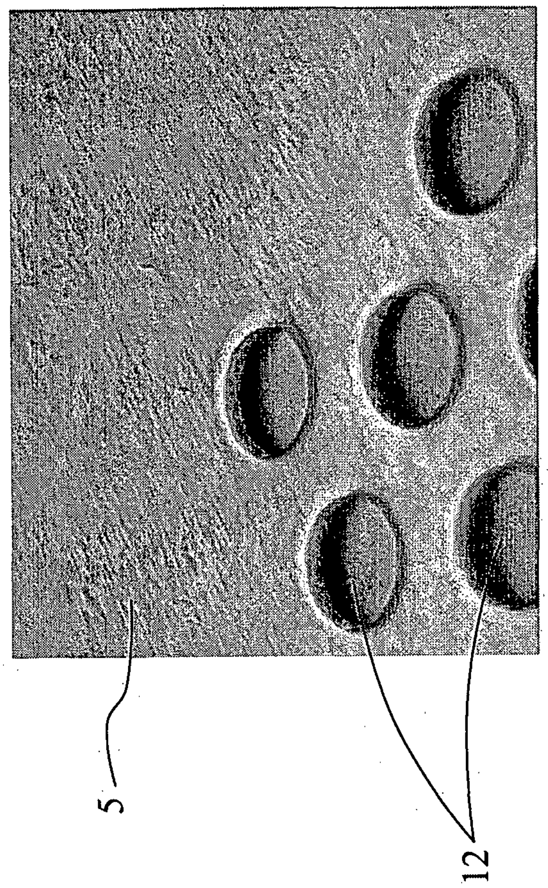

FIG. 7

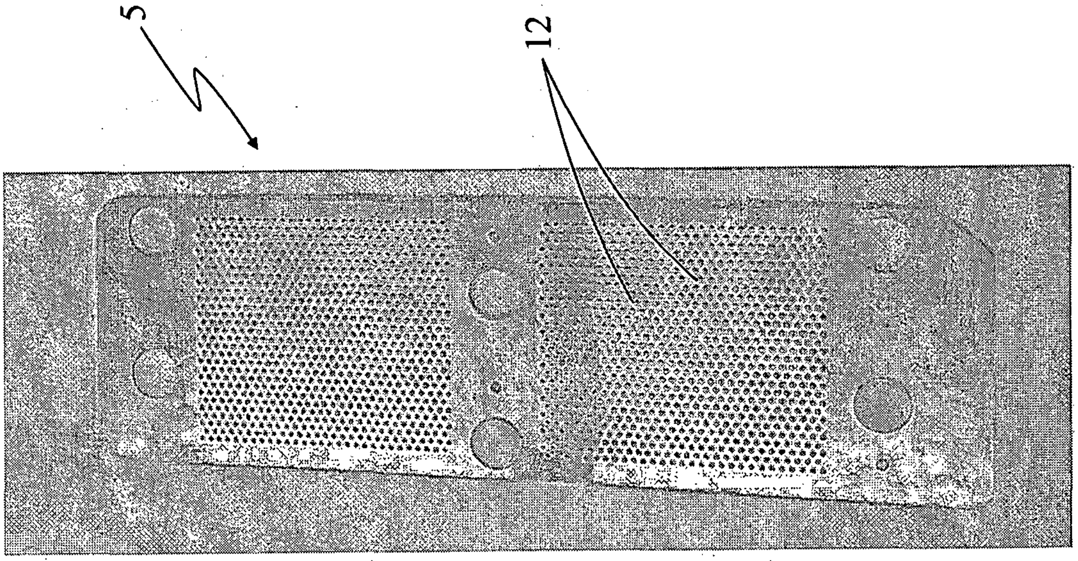

FIG. 6A

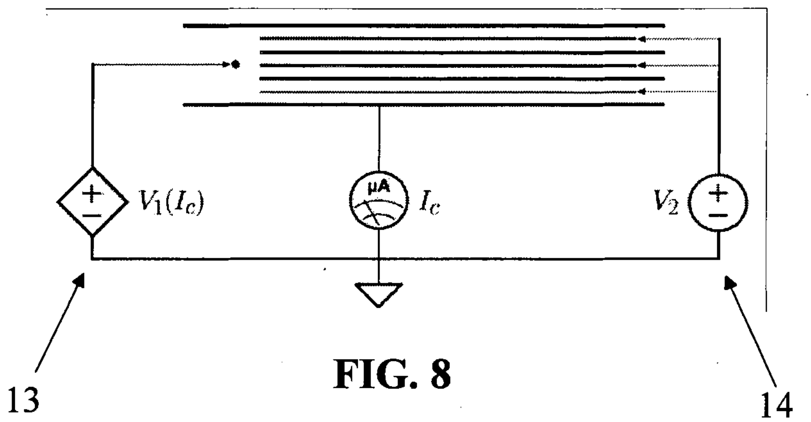

FIG. 8

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 3664092 A **[0032]**
- WO 0164349 A **[0033]**
- US 2005150384 A **[0035]**